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UNIVERSITY OF ALBERTA

INCORPORATING WEATHER EFFECTS IN PROJECT SIMULATION

BY

RODNEY JAY WALES

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE**.

DEPARTMENT OF CIVIL ENGINEERING

Edmonton, Alberta

Spring 1994

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FACULTY OF GRADUATE STUDIES AND RESEARCH

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ABSTRACT

Incorporating uncertainty variables in project simulation studies can be achieved through several methods. The most widely used technique models activity durations with statistical distributions to reflect uncertainty in actual activity durations. An alternative approach is to model the underlying random process responsible for variation and quantify impacts on activity durations. Productive capability of workers and equipment performing construction tasks is affected by the occurrence of random processes such as weather. Therefore, the time required to complete activities varies in accordance with the occurrence of such random phenomena. The methodology presented herein models the occurrence of such factors, quantifies impact on productivity, and adjusts activity durations to reflect current project conditions. This approach requires the use of combined discrete-event continuous simulation modeling concepts. Continuous simulation is required to model activity durations while task relationships are captured using discrete-event concepts. This represents an alternative approach to simulating project schedules. Most previous project scheduling models are discrete-event oriented. Tests of this modeling concept prove that the method provides accurate results and has clear advantages over existing techniques.

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LIST OF SYMBOLS

$\rho_0(i,j)$ = lag 0 cross correlation coefficient between variables i and j
$\rho_1(i)$ = log 1 serial correlation coefficient for variable i
$\overline{X}_d^0(i)$ = periodic mean of variable i on dry day d
$\overline{X}_d^1(i)$ = periodic mean of variable i on wet day d
$\sigma_d^0(i)$ = periodic standard deviation of variable i on dry day d
$\sigma_d^1(i)$ = periodic standard deviation of variable i on wet day d
α = alpha parameter of two-parameter gamma distribution
β = beta parameter of two-parameter gamma distribution
Γ = gamma function
μ = mean value of a sample
σ = standard deviation of a sample
$\rho_1(i,j)$ = cross correlation coefficient between variables i and j with variable j lagged 1 day with respect to variable i
σ^2 = variance of a sample
$\varepsilon_{y,d}(i)$ = matrix of independent random components
$\chi_{y,d}(i)$ = residual element for year y and day d for variable i
# = activity number
A = matrix defined to preserve time dependence and interdependence structures of historical residual weather series
B = matrix defined to preserve time dependence and interdependence structures of historical residual weather series
b_{ij} = row i, column j element of matrix B
BW = back wall
C = degrees Celsius
CDF = cumulative density function
c_{ij} = row i, column j element of matrix C
CPM = critical path method
CYCLONE = cyclic operations network
dd = day (two-digit)
e = natural logarithm
exp = value raised to the power e
f(z) = value of function f with z as the argument
FRP = form, rebar, pour
M_1 = lag 1 covariance matrix of residual series
mm = millimeters
mmm = month (three-digit)
M_o = lag 0 covariance matrix of residual series
MUD = model for uncertainty determination
$n_{i,j}$ = count of transitions from state i to state j

n_i = count of all transitions from state i to other states
N_i = number of days in state i
P.F. = productivity factor
PDF = probability density function
PERT = program evaluation and review technique
$P_{m,d}(j/i)$ = probability of transiting from state i on day d-1 to state j on day d in month m
$P_{m,d}(W/W)$ = probability in month m of two wet days in succession
$P_{m,d}(W/D)$ = probability in month m of a dry day followed by a wet day
$P_m(i)$ = probability of a day in month m being in state i (i.e. wet or dry)
$P_m(W)$ = probability of any given day in month m being wet
$P_{y,d}$ = depth of precipitation in mm
W_{in} = input path i weight value to node n
WW = wing wall
x = function argument
X_i = input path value to node n
X_m = total number of days in month m for x years of record
$X_{y,d}(i)$ = value of variable i for year y and day d
Y_n = node n output value
yy = year (two-digit)
z = function argument
$z(n)$ = weighted summation for node n

CHAPTER 1: INTRODUCTION

Construction management involves planning, scheduling, and controlling project activities to meet project objectives (Lewis 1993). Project objectives include meeting cost and budget constraints, sequencing operations properly, efficiently allocating resources, maintaining desired performance levels, and completing the project on time. Many techniques have been developed to assist the construction manager in meeting these objectives.

Bar charts are one of the early forms of project management tools. A bar chart graphically describes project activities on a time-scale. After bar charts came network techniques that show project activities, durations, and logical task interrelationships. Critical path method (CPM) is a network technique used in construction. Line-of-balance charts, velocity diagrams, progress curves, and others have also been developed to assist managers in their work.

These techniques provide assistance in establishing project plans and measuring and improving performance. However, they fail to recognize the inherent variability observed in construction projects. It is a well-known fact that construction projects are subject to variability due to design changes, unexpected soil conditions, adverse weather, and others that lead to variation in the project cost and schedule. Efforts to quantify the impact of variation in the project began with the Program Evaluation and Review Technique (PERT). This method recognizes variation in the schedule by describing activity durations with Beta distributions and associating probability with the schedule.

Computer simulation is another tool that integrates variability into project management techniques. Simulating construction processes involves applying random number techniques to establish anticipated levels of production and solving some of the problems related to the randomness of construction operations (AbouRizk et.al. 1992). Evaluation of expected project cost (e.g. range estimating), project duration, and expected production of various processes are some of the simulation applications in construction.

SIMULATION MODELS IN CONSTRUCTION

Increased personal computer use allows the application of more sophisticated management tools. In particular, simulation became more accessible due to the desk top computer and development of simulation languages. Simulation languages allow simulation to be performed by a person unfamiliar with random number techniques. One of the earliest construction applications of simulation methods was in a gaming context (AbouRizk et.al. 1992). The advent of simulation methods in construction led to simple networking concepts as a modeling framework for studying construction operations (AbouRizk et.al. 1992).

Halpin (1973) developed the CYCLONE format at the University of Illinois that has become the basis of a number of construction simulation systems. A great deal of simulation research has been motivated over the past two decades due to success of CYCLONE. Halpin (1990) and Halpin and Riggs (1992) give numerous examples of construction process models including; earth moving, pavement construction, high-rise building concrete placement, cladding, tunneling, underground pipe-jacking, and many others.

Relatively little work has been done in the area of project level simulation models. Most of the work that has been done is of a hybrid nature. Generally, the models are CPM based and a form of Monte-Carlo simulation allows evaluation of the network (AbouRizk et.al. 1992). Significant work in this area include that done by Benjamin and Greenwald (1973), Carr (1979), Dabbas and Halpin (1982), Woolery and Crandall (1983), and Ahuja and Nandakumar (1985).

Benjamin and Greenwald (1973) explored the effects of weather on construction projects using a form of simulation. Their work focused on cost and schedule impacts of daily weather events. A CPM based model of the project is used and simulation proceeds by advancing through the project day-by-day making work no-work decisions based on weather conditions. Costs associated with the decision to work or not to work are accumulated to determine project cost at the end of simulation. Project duration is determined when all activities are completed. Random number techniques are applied in various elements of the models presented in terms of daily weather conditions or probability that a day is suitable for work.

Carr (1979) developed a model for uncertainty determination (MUD) to quantify uncertainty in the project schedule. Carr recognized that activity durations are dependent on the outcome of random variables such as crew productivity, subsurface site conditions, effectiveness of supervision, and weather and as such are also random variables. An important contribution of Carr's work was that he recognized that many of the random variables are shared between project activities and therefore the durations are not independent of each other. MUD consists of a CPM schedule of the project and a two-step simulation procedure. The first step is to determine "raw" activity durations based on random variables that are independent of time of year. A duration for each activity is sampled from a distribution that contains the effects of the "independent of calendar date" variables considering activity interdependencies. Random variables "dependent on calendar date", such as weather, are incorporated in the second step. Sensitivity of each activity to the calendar dependent variables is determined and incorporated as simulation proceeds day-by-day according to the CPM network. This procedure produces an estimate of activity times and project duration considering uncertainty variables.

Dabbas and Halpin (1982) developed a simulation model that integrates project and process level planning and management. Traditional scheduling methods such as CPM require the user to estimate project level activity durations such as placing concrete for the first floor of a high-rise building. Many times project level activities consist of process level work tasks and technologies. For example, the placing of concrete involves a series of repetitive tasks that involve the cyclic movement of or sharing of resources. Their model provides the capability to estimate project level activity durations using a process level simulation network.

Woolery and Crandall (1983) developed a Monte-Carlo based project network model consisting of dependent and independent random variables. Their method involves sampling each activity duration in the network from a distribution describing its duration under optimal conditions. A series of time distributions for various problems that may lengthen the activity completion time are also sampled. They then combine the time extensions to determine the cumulative effect of the activity delays based on independence or dependence of the delay types. For example, an activity that is stopped due to weather will not be affected due to a labor shortage. The authors discuss an iterative method to account for this. The cumulative delay time is added to the optimal duration to determine the "actual" duration. Simulation of each activity proceeds in this manner.

Ahuja and Nandakumar (1985) developed a CPM based simulation model, PRODUF, that estimates project completion times based on the occurrence of uncertain, but predictable, variables that affect activity durations. Their basic approach involves a computer model that simulates the expected occurrence of uncertainty variables and determines impact on a daily basis. The impact is incorporated in the scheduling calculations to make forecasts of project completion time. They use the approach suggested by Woolery and Crandall (1983) to correct for overlap of time extensions due to uncertainty variables. The distribution of simulated project completion time is used to associate probability with given project completion time estimates.

ELEMENTS OF PROJECT SIMULATION MODEL

The model presented in this research attempts to address the issues put forth by previous researchers and construction simulation practitioners. We have also attempted to build upon the positive aspects of the previous models and enhance existing project management techniques. To be accepted in the construction environment simulation must be presented in a very simple and graphical context (AbouRizk et.al. 1992). This model is designed to maintain simplicity and support graphical interfaces for the end user.

Size and complexity of project networks often cause difficulty when modeling projects in a simulation format. In general, the time and effort invested in building a simulation model does not provide a positive return on investment (AbouRizk et.al. 1992) Since CPM network techniques are the leading form of project level control (AbouRizk et.al. 1992), the model developed in this research uses existing CPM networks and invokes simulation procedures upon the network. Therefore, additional work required of the user when using this system is limited. Size still remains a problem due to limitations of the general purpose simulation language used in this work. In future versions of the general purpose simulation language we expect that capacity will be increased thus eliminating this problem.

Ahuja and Nandakumar (1985) state that: "for more reliable estimates of project completion time, it would be beneficial to develop a computer model that simulates the expected occurrence of uncertainty variables, explicitly analyze and quantify their combined impact, and incorporate it in activity duration estimates." In this model weather is chosen as the uncertainty variable to demonstrate the implementation procedure. Weather is generated by a stochastic model conditioned to the weather conditions observed in the area where the project will occur. Determining the impact of weather conditions on the project takes is done using neural networks trained on existing productivity data and the corresponding weather conditions. The neural network trains itself to recognize the relationships between observed weather conditions and productivity. Incorporation of productivity in the activity duration estimates is accomplished by a daily simulation procedure where the amount of work accomplished in a given activity is related to the calculated productivity factor. When sufficient work has progressed for the activity such that its work requirement is satisfied then follower activities are allowed to commence. This is achieved through the use of combined discrete-event continuous simulation modeling. This procedure resembles that taken by Ahuja and Nandakumar (1985).

Addressing the issue of the combined impact of uncertainty variables on productivity was handled previously by Woolery and Crandall (1983). We have taken a different approach to this problem. Although we do not address this issue explicitly in this work, since we are only analyzing one uncertainty variable, the problem is dealt with inherently through the use of neural network technology. When the network trains itself from historical data it inherently learns the mutually exclusive and non-mutually exclusive patterns observed in the actual data. Chapter 4 discusses neural networks where this concept is explored further.

CONCLUSION

The following chapters describe the various elements of the project simulation model in detail. Chapter 2 describes the combined discrete-event continuous simulation modeling concepts. Chapter 3 covers the weather generation scheme employed in the model. Chapter 4 describes the neural network technology and how it is incorporated. Finally, chapter 5 summarizes the project simulation model, addresses the significance of the work that has been done, discusses some limitations of this model, and outlines future research directions that can be taken with this work.

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CHAPTER 2: PROJECT SIMULATION MODEL

INTRODUCTION

Progress on construction projects is subject to many factors that lead to uncertainty in the final duration and cost. Factors such as weather, material arrivals, design changes and rework, soil conditions, labor supply, and government regulations, impact project progress. Since projects are a unique, one-time undertaking we only have one attempt to execute a successful project. This places great emphasis on developing an effective project plan in an uncertain environment.

An effective project plan must consider uncertainty and its impact on the project schedule. Often, intuition and knowledge of project planners is the only basis for considering uncertainty. Development of a method to characterize variability within the project will assist project planners in this task. This will enable planners to quantify uncertainty in the project schedule and make well-informed decisions in order to minimize its effects. Then, they can experiment with the model to determine the most effective project plan. Simulation is ideally suited to this task.

The objective of this research is to develop a project simulation model that builds upon existing techniques used in the industry. This model must accurately predict the arrival process of uncertainty factors. Then, the model must determine the impact and reflect this impact in the project schedule. The model must also provide useful output in order to understand behavior, analyze performance, and predict results. This output provides a basis for evaluating the project plan. For this work, estimates of project milestone and completion time provide an effective evaluation of the project plan.

Organization of this paper is as follows. The first section provides an overview of existing project simulation methods and introduces the method employed in this research. The next section describes the elements of the model and how they function together. The third section describes operation of the model during simulation. Next, we discuss how to use the simulation results. The final section highlights advantages of this method and identifies future research directions.

ANALYZING PROJECTS USING SIMULATION

A construction project is subject to many factors that lead to variability in its progress. These factors occur in an uncertain manner; therefore, a construction project is a stochastic system since it evolves in a way that is not completely predictable. Modeling stochastic systems requires that variability of the elements in the system be characterized using probability concepts (Pritsker 1986).

One common approach captures project schedule variability in activity duration estimates. Activity durations vary in accordance with some underlying random process (AbouRizk and Halpin 1992). Therefore, we estimate the underlying distribution of the random process. Several methods may be used to do this. A common method is to fit a standard statistical distribution to a collection of sample observations. Then a random sample from the standard statistical distribution determines the activity duration for each simulation run. Figure 2-1 illustrates this process.

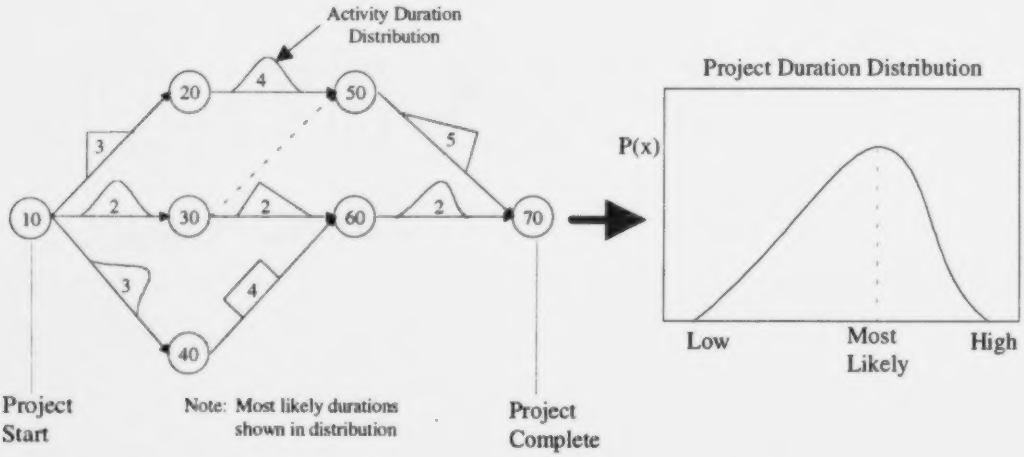
Activity Duration Distribution
20
4
50
3
5
10
2
30
2
60
2
70
3
4
40
Project Start
Note: Most likely durations shown in distribution
Project Complete
Project Duration Distribution
P(x)
Low
Most Likely
High

Figure 2-1 Discrete Event Project Simulation

Figure 2-1 shows a CPM network used to describe the logical order of the project activities. Statistical distributions represent each activity's duration with the most likely duration shown on the activity. During each simulation run activity times are sampled from the distributions describing activity durations and scheduling computations performed to determine project completion time. Executing many simulation runs provides a sample of project completion times. A statistical distribution fit to the completion time sample provides statistical information regarding project completion dates. Information such as probability of completing within a specified time, optimistic and pessimistic schedules, and most likely project duration can be derived from the simulation output. Information regarding intermediate project milestones may also be obtained in a similar manner.

To describe the simulation procedure consider Activity 10-20 from Figure 2-1. A detailed illustration of this activity appears in Figure 2-2. Sample activity durations were gathered on previous projects and it was determined that a triangular distribution with an optimistic value of 1 day, a pessimistic value of 5 days, and a most likely duration of 3 days, accurately describes the possible durations for this activity. The probability density function (PDF) is illustrated in Figure 2-2. The associated cumulative density function (CDF) appears above it. Activity 10-20 can start on day zero (0) of the project according to the CPM network. To determine a duration for the activity a uniform random number between zero (0) and one (1) is sampled. Assume a value of 0.875 is sampled. Mapping this value onto the CDF yields an activity duration of 4 days. The simulation clock advances from zero (0) to four (4) days. Then, the duration of activity 20-50 is sampled and the process continues. Each activity is processed in a similar manner. This simulation methodology is known as discrete-event simulation; where, event times occur at the start and end of activities. The simulation clock progresses through time by moving from event to event.

Some limitations of this type of modeling include the following. Activity durations are assumed to be independent random variables. On most projects crews, supervision,

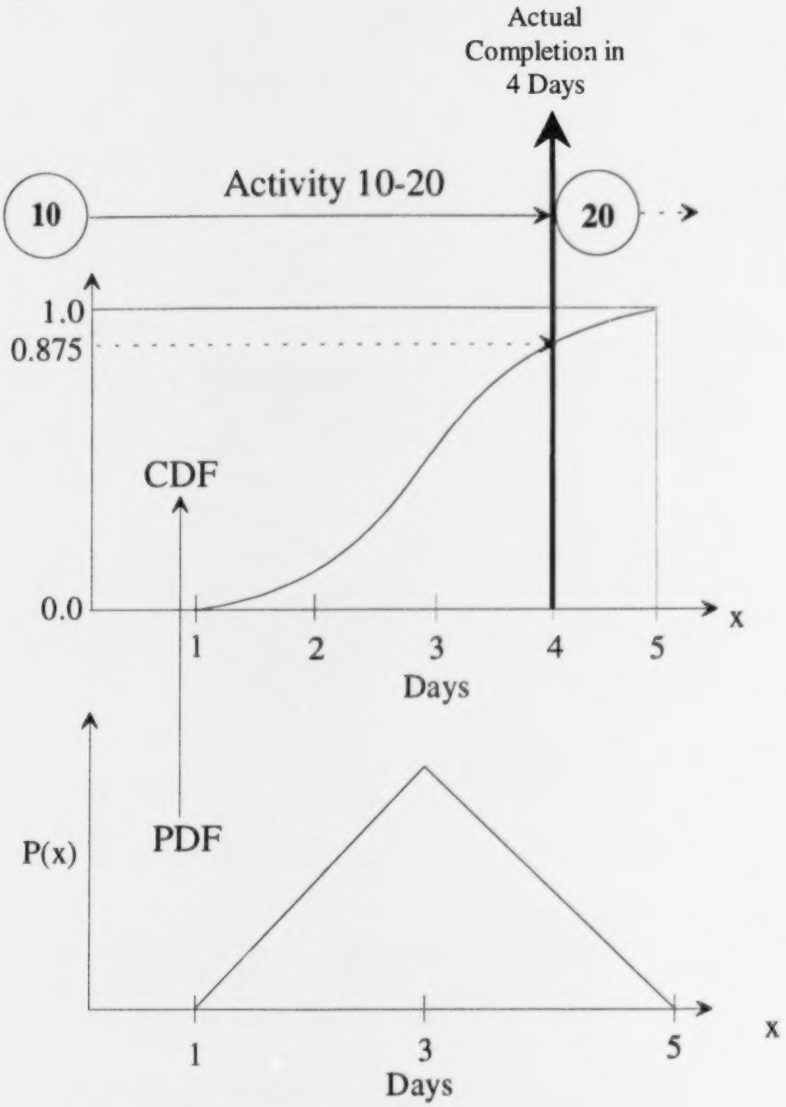

Figure 2-2 Discrete Activity Simulation

site conditions, materials and weather are shared between many activities (Carr 1979). Therefore, activity durations are not independent of each other. For example, two separate earthwork activities proceeding simultaneously on the same site are likely subject to similar weather conditions. In cases where properties of the underlying random process change, the distribution must also change to reflect the new conditions. Therefore, new duration samples must be gathered to fit a statistical distribution that reflects the changed conditions. To illustrate this phenomena consider executing a project in two separate locations where rainfall is much greater in one location than the other. Duration distributions of activities sensitive to precipitation impacts must reflect the extra rainfall. As a result, two different distributions describe the same activity for separate locations.

The discrete event approach does not establish the cause of variation in the project schedule. If weather causes significant delays in a construction project the user is not provided with the cause of delay. Therefore, corrective action can not be taken that would reduce delays such as providing weather protection. The cause of uncertainty must be known in order to effectively manage uncertainty in the schedule.

Another limitation of this modeling procedure deals with seasonality of underlying factors. Again, consider weather. When an activity is delayed into a different season, the duration distribution can vary. For example, steel erection suffers a loss of productivity during cold weather resulting in a longer, less certain duration. If an activity is delayed from a period of warmer weather to a period of colder weather then the statistical distribution describing the duration must be adjusted accordingly to suit the season.

Researchers such as Carr (1979), Ahuja and Nandakumar (1985), and Woolery and Crandall (1983) developed methods to incorporate uncertainty in project simulation models considering activity interdependencies. However, these models do not directly address the issue of factor variation from site to site and time of year. Furthermore, the cause of delay is not established explicitly. An alternative approach that addresses all of the limitations identified in the previous section involves modeling the underlying random process causing variability in the activity duration. Work stoppages and productivity variation is determined through a productivity model relating uncertainty factors to their consequences. Activity durations are adjusted accordingly.

This modeling methodology is demonstrated by incorporating weather effects in a project simulation model. Weather is chosen since it is a very difficult factor to model and has a large impact on construction productivity. Successful incorporation of weather effects in a project simulation model will demonstrate how other factors can be included.

PROJECT SIMULATION MODEL

Project simulation is achieved by maintaining an internal simulation clock that is incremented by uniform increments of one day each. On a given day the project events are scanned, weather conditions are generated, and productivity of scheduled tasks is evaluated. Progress is then credited to scheduled activities based on the evaluated productivity. When enough progress is achieved the activity is complete and followers can proceed. The daily approach is an important aspect of the model since weather tends to change daily and it is desirable to capture this effect. Furthermore, weather exhibits seasonal trends and this can also be captured through this approach. Figure 2-3 illustrates the overall modeling concept. Appendix A lists the relevant computer code associated with the project simulation model.

A bar chart schedule of the sample project given in Figure 2-1 is shown in Figure 2-3. The heavy bars represent the schedule based on most likely activity durations. The histogram shown beneath the bar chart show the productivity factors determined based on the weather conditions generated for one simulation run. The light bars show the resulting schedule based on the productivity profile for this simulation run. Due slightly unfavorable conditions resulting in lower than assumed productivity the project requires 13 days to complete rather than the scheduled time of 12 days.

The tracking process is illustrated in Figure 2-4 by following the progress of Activity 10-20. The first step is to determine the activity duration. In this model we determine a single time estimate rather than building a statistical distribution to describe the duration. This estimate is made on the basis of assumed productivity. The assumed productivity is that productivity one would normally expect to achieve. The most-likely duration for the activity in the previous example was 3 days. Therefore, based on the assumed

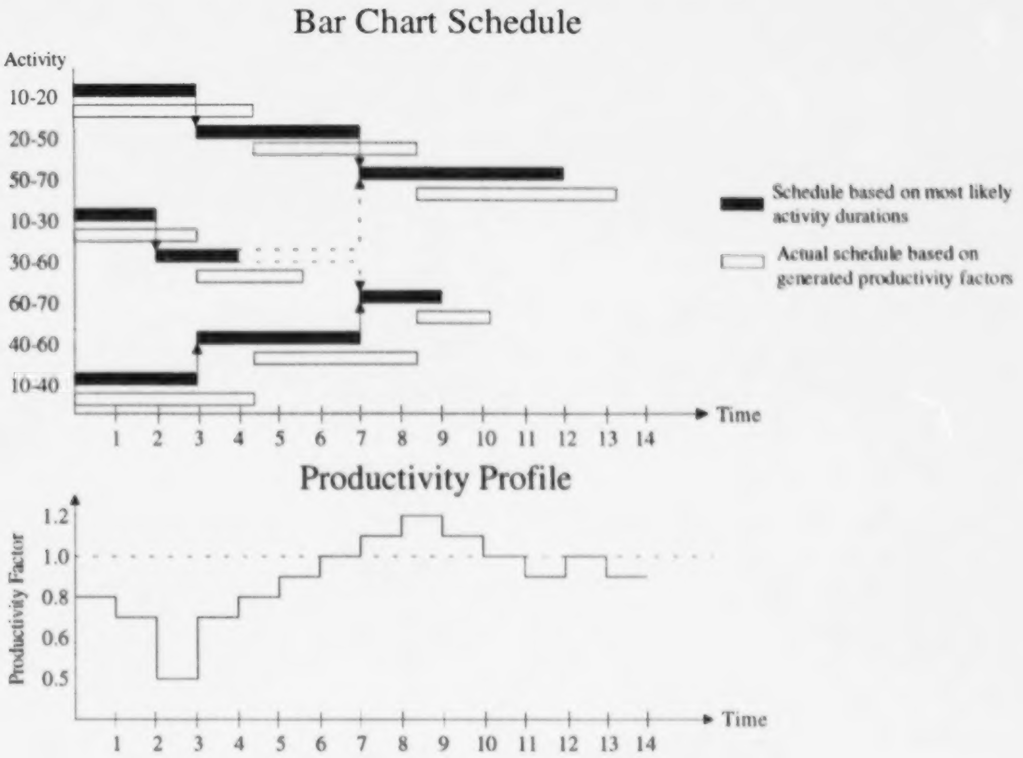

Figure 2-3 Daily Simulation Methodology

productivity used at the time of estimating we determined that this activity would require 3 days to complete.

The first step in the simulation procedure for the activity is to generate weather conditions for the first day of production. Weather conditions are generated and productivity is determined. Productivity is defined in terms of a productivity factor.

$$\text{Productivity Factor} = \frac{\text{Achieved Productivity}}{\text{Assumed Productivity}} \quad \dots\dots\dots \quad (1)$$

Productivity factors can be greater or less than one (1.0) depending on whether productivity was better than or less than the assumed productivity.

Activity progress is evaluated based on the productivity factor for the day. Since activity duration estimates are based on assumed productivity, multiplying the estimated duration by the productivity factor gives the actual duration of the activity. Considering 1

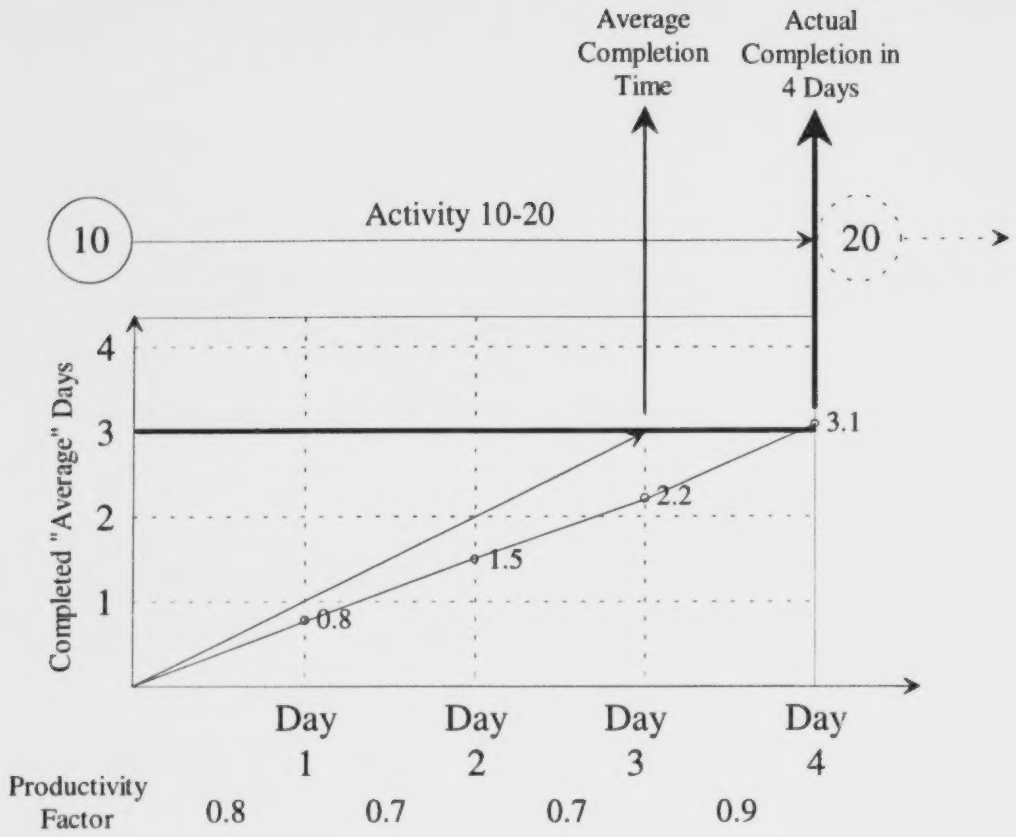

Figure 2-4 Continuous Activity Simulation

day increments multiplying the assumed duration for the day (1 day) by the productivity factor for the day gives the actual production for the 1 day period. In Figure 2-4, the productivity factor for day 1 is 0.8. Therefore, the activity is credited 0.8 days of production towards the 3 day threshold required to complete the activity. The simulation clock now proceeds to day 2 of the activity. Weather conditions are generated and productivity is determined for this day. Conditions deteriorated slightly and a productivity factor of 0.7 is obtained. This value is added to the progress from the previous day to obtain activity progress of 1.5 days. The activity is now 50% complete at this point after 2 days of production. The clock advances to the next day and the same procedure is repeated. A productivity factor of 0.7 is obtained and activity progress is now 2.2 days.

On the fourth day of production productivity increases to 0.9 and activity progress is now 3.1 days. Since this is greater than the threshold value of 3 days the activity is now complete. Due to lower than assumed productivity the activity required 4 days of production to complete rather than the 3 days obtained at the estimating stage. When the activity is completed follower activities in the network can then proceed. All activities in the network are processed in a similar manner.

This example results in the same outcome as the example in Figure 2-2, however, the process of arriving at this result is very different. With this methodology it is possible to model the actual factors that influence productivity on an activity from period to period. Therefore, the model is capturing the underlying randomness at the level that it actually occurs. For example, weather has significant impacts on productivity for many construction activities. With this approach, weather is modeled on a daily basis and the results transposed into a productivity value to evaluate performance for the specific day. For this approach to work the weather modeling procedure must generate accurate values and productivity evaluation must reflect actual relationships between weather conditions and productivity.

This methodology combines discrete-event simulation concepts with continuous simulation modeling. In the project simulation model activity relationships are maintained through discrete-event concepts while activity durations are modeled in a continuous manner. Discrete-events occur at the start and end of activities signaling a change in the state of the system. At this point we close out activities that have been completed and start new ones. Modeling the events between the start and finish of activities occurs through continuous procedures.

MODEL COMPONENTS

The simulation model consists of 3 separate components that function together to provide a combined discrete-event continuous simulation model. The first component of the model is the project network. This is a model of the project activities describing their logical order and specifying their assumed duration. These relationships must be specified to perform project simulation. CPM is a popular technique used in the construction industry to describe the construction schedule. An objective of this research is to build upon existing project management techniques. To facilitate the use of CPM networks in the project simulation study we have developed a program that automatically converts the CPM network into an equivalent simulation network of the project. The algorithm and a sample session of the program is provided in Appendix A. Pritsker, et.al. (1989) illustrate a simulation method for describing project networks. This network method is used in this work. Figure 2-5 shows a CPM network and its corresponding representation in SLAMSYSTEM (Pritsker Corporation 1990). Items not shown in Figure 2-5 that are required in the overall project simulation model are: the calendar network that maintains calendar date, coordinates weather generation, and determines productivity; detect nodes used to track activity progress; and the associated user written code. These items are covered in greater detail in later segments of this work.

A second component of the simulation model is the generation of weather variables. We have taken the approach used by Richardson (1981) for stochastically generating daily weather variables. Richardson's approach is used since it is flexible, accurate, and can be efficiently programmed for use in the simulation model. The weather generation process involves characterizing weather patterns from historical records and using these parameters when generating new sequences of variables. The complete procedure is described in Chapter 3 and Appendix B. Weather variables studied in this work are daily maximum temperature, daily minimum temperature, and precipitation. These variables are selected to illustrate the process of generating new sequences of weather having the same underlying distributions as the historical data set for a region. By obtaining historical weather records and following the same procedure the user can incorporate other weather variables such as relative humidity, wind, solar radiation, etc.

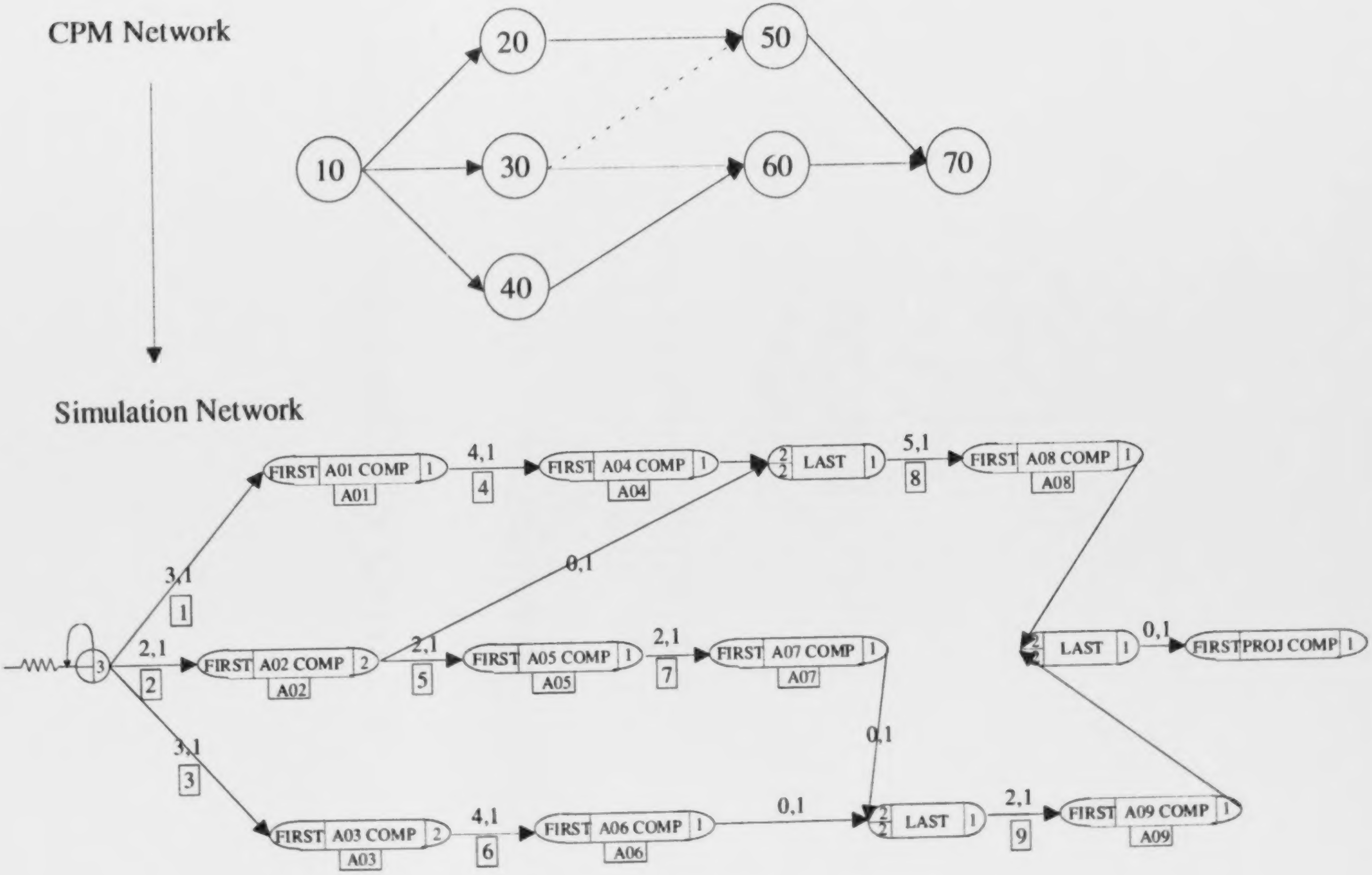

Figure 2-5 SLAMSYSTEM Project Network

The third component of the model is the determination of productivity based on generated weather conditions. Application of neural networks accomplishes this task. A neural network is trained based on historical records of weather conditions and the productivity achieved under those conditions. After training is complete the neural network recognizes the relationship between the various weather parameters and the achievable productivity under those conditions. During simulation the network is presented with weather conditions for the day and productivity is determined. Different types of activities require separate neural networks since productivity is affected to different degrees. For example, earthwork activities are more sensitive to precipitation than activities that take place indoors. By classifying activities into categories a neural network can be developed for each category instead of developing a separate network for every activity. The neural network aspect of this work is covered in detail in Chapter 4.

The simulation clock provides a link between the three components. All three components function in response to the simulation clock. The simulation clock advances through time in daily increments and the other three components are triggered when the simulation clock advances from one time step to the next as illustrated in Figure 2-6. The simulation model components are covered in detail in Appendix A.

Simulation begins at day 1 of the project. At this time all activities scheduled to start are allowed to proceed. Weather conditions for the day are generated. Productivity based on the weather conditions is determined for each type of activity in the project. Each activity that is proceeding is credited progress for day 1 based on the determined productivity factor. A check is made to determine if any activities are complete. Completed activities are stopped and followers to that activity are scheduled to begin immediately. Future model implementations could be programmed to begin the activity immediately or wait until the next day to proceed with follower activities depending on the time remaining in the current day. The simulation clock now advances to day 2 of the project. Again, this cycle is repeated. This continues until all activities in the network are

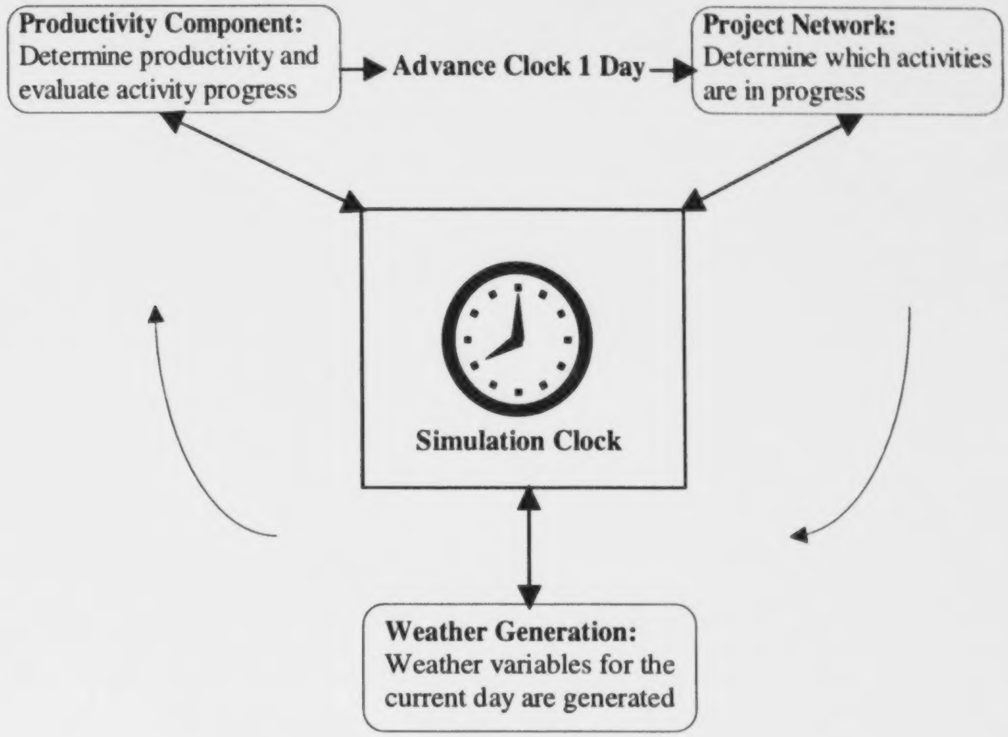
Productivity Component:
Determine productivity and evaluate activity progress
Advance Clock 1 Day
Project Network:
Determine which activities are in progress
Simulation Clock
Weather Generation:
Weather variables for the current day are generated

Figure 2-6 Synchronizing Model Components

completed and a project completion time is determined. After many simulation runs a range of possible completion times is determined and statistical interpretations are made.

USING THE RESULTS

Results of the simulation experiment are used in a number of ways to improve the project plan. Simulation is a method that allows us to execute the project a number of times to determine valuable management information. The most obvious result of a project simulation study are probabilistic estimates of project milestones and completion time. Risk can be associated with milestones or completion times by determining the probability of meeting specified targets. For example, a manager might want to determine the project completion time he/she will have a 90% chance of meeting. Furthermore, the most optimistic and pessimistic schedule is determined. Another important result is the calculated variance of project milestones and completion time. The larger the variance the more uncertainty is associated with the schedule. Large variances imply less confidence with a given time estimate.

Establishing a realistic schedule allows management to develop an adequate pace of performance. Project managers can use the established baseline to compare performance and take corrective action when necessary. When performance is below the performance baseline management is warned that schedule slippage is likely to occur. Without a realistic schedule the manager can always assume that the schedule is too optimistic and pay little attention to such warnings.

Simulation provides an opportunity to investigate alternative project plans and recognize potential delays early. Simulating various project plans provides a probabilistic measure of performance for each plan. The manager can then implement the plan providing the best performance. Potential project delays are readily identified in this process during the planning stages of a project. Greater recovery is possible if potential delays are recognized earlier in the life of the project (Ahuja and Nandakumar 1985). Delay causes are provided, therefore, we can investigate alternative measures that may reduce uncertainty. If weather is a problem then providing weather protection for some activities may become a cost effective solution. Simulating the project with weather protection and without weather protection will determine if weather protection is economical. Rather than correcting problems after the fact, management can take steps to avoid their occurrence initially.

Simulation results can provide the criticality index of each activity. Criticality index is the number of times the activity is on the critical path divided by the number of simulation runs. Devoting more time and effort to activities with high criticality indices will help them remain on schedule. This way the entire project will remain on schedule. Extra resources can be borrowed from activities with low criticality indices to ensure critical activities remain on schedule.

Simulation results can assist in after-the-fact analysis of construction projects (AbouRizk and Wales 1993). Quantifying delay impacts in the project schedule is possible. Consider a 3 month project that has been delayed from an August 1 start date to a September 1 start date. In Alberta, this delay causes the project to proceed under harsh November winter conditions. Therefore, the project may require 3.5 months to complete under these conditions. Instead of being complete at the end of October the project will not finish until mid-December. A one month delay at the start of the project caused a delay of 1.5 months at the end of the project. If an owner caused the initial delay then the contractor may be entitled to compensation for an extra two weeks plus any extra expenses incurred to operate under winter conditions. In this type of analysis the actual weather conditions experienced are known and can be used as an input to the model.

CONCLUSIONS

This modeling procedure has many advantages over traditional project simulation techniques. First, the model is portable. It can be used in many different locations that experience different weather conditions. In the traditional model the activity duration distributions had to be adjusted to reflect changed conditions. In this approach it is only necessary to input the changed weather parameters determined for the project location. Then the activity durations adjust automatically to the conditions under which the project will be executed. Simulation occurs in a manner that reflects actual occurrences on a construction project. An improved simulation model results when a more accurate representation of the real system is developed.

The model can be enhanced by generating the occurrence of other factors leading to uncertainty in project duration. This requires capturing the arrival process of those factors in a way suitable for the factor being considered. Productivity is determined by adding the extra factors to the neural network and retraining. What is presented here is a framework for the eventual incorporation of all uncertainty factors in project simulation. Other aspects that may be added include cost and resource elements. In this way resource requirements can be monitored and costs can be determined for different schedules and plans.

This work demonstrates that combined discrete-event continuous modeling is a viable alternative to the approach taken in the past. This modeling approach has several advantageous features. The concept is proven by incorporating weather effects in the project simulation study. Weather is a very difficult parameter to incorporate. Since it could be accurately modeled and incorporated effectively, other factors can be added using similar concepts. Neural networks show great promise in modeling construction productivity. The nature of neural network technology is ideally suited to the task of modeling construction productivity for simulation. SLAMSYSTEM provides an efficient link to combine the various aspects of the model. Together, an effective project simulation modeling environment is created.

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CHAPTER 3: STOCHASTIC GENERATION OF WEATHER VARIABLES FOR CONSTRUCTION SIMULATION[1]

INTRODUCTION

Construction projects are subject to effects of numerous factors leading to uncertainty in the timing and sequence of project activities. Uncertainty factors such as weather, soil conditions, resource availability, material arrivals, and others can be modeled as stochastic processes. It is advantageous from a management and planning perspective to model the occurrences of these factors, quantify their effects, and determine their impact on the project schedule to improve the overall project plan.

Computer simulation is effective in performing these functions. Specifically, combined discrete-event continuous simulation modeling may be utilized, where, the network schedule (e.g. CPM or PERT) is modeled in discrete event format, and other uncertainty factors as continuous stochastic processes. Project simulation modeling in this fashion requires:

a. precise stochastic models capturing arrival processes of uncertainty factors,
b. combined discrete-event continuous simulation modeling methods, and
c. accurate quantification of uncertainty factor impacts on productivity.

The objective of this paper is to introduce an integrated model that can enhance project scheduling and planning. The focus of this work is on weather as it is representative of other continuous random phenomena in construction. On most construction projects weather impacts many activities and therefore will cause significant uncertainty in project scheduling. Similar modeling strategies may also be developed for other uncertainty factors following the same approach presented herein.

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[1] A version of this chapter has been submitted for publication. ASCE, Journal of Construction Engineering and Management.

BACKGROUND

Accurate forecast of project milestones and completion time allows management to establish the rate of completion of project activities and an accurate baseline to compare performance. A realistic forecast of project completion time is important since the schedule affects project costs. Variability in the project schedule makes estimating the project completion time a difficult task. This has led to techniques such as the program evaluation and review technique (PERT) and Monte-Carlo-based simulation which quantify the impacts of uncertainty variables. The PERT system assumes project activity durations are independent random variables (Harris 1978) making PERT probabilities unsuitable for many construction projects (Carr 1979). Many Monte-Carlo-based simulation models make the same assumption. Finally, managing uncertainty in the schedule is difficult since these methods do not establish the causes of uncertainty.

Carr (1979) presented a Monte-Carlo simulation based method that accounts for task interdependencies by maintaining time-dependent relationships among actual activity durations. Ahuja and Nandakumar (1985) extended these concepts further and included uncertainty variable generation and quantification of their impact. Both methods first simulate the impact of uncertainty variables independent of time of year and then simulate daily impacts of time-dependent variables. Improvements to these models can be achieved by implementing daily stochastic generation of uncertainty variables and quantification of uncertainty impacts through quantitative rather than qualitative methods.

This modeling implementation is applicable to many of the available general purpose simulation languages. SLAMSYSTEM (Pritsker Corporation 1990) was chosen in this project for its combined discrete-event continuous modeling capability.

MODELING METHOD

Current project scheduling practices almost always include CPM or Precedence network schedules. In this model we take an existing network and automatically convert it to a SLAMSYSTEM simulation model in order to make use of current scheduling philosophies. Stochastic processes are then superimposed on the schedule to get a final accurate representation of the project schedule as shown in Figure 3-1.

The model operates in the following sequence: weather conditions are generated for a given day; progress is estimated; and then credited to activities scheduled for that particular day. Progress is estimated by employing a trained neural network which accepts weather parameters as input and estimates productivity as output. When an activity is credited with enough progress it is complete and its followers may be scheduled for work. This process is detailed in the flow chart given in Figure 3-2.

A sample of project completion times (or any milestone event) is obtained by repeating the experiment many times. The resulting sample will categorize the project completion time and may be used to estimate the mean, variance, and probability of completing the project at specified times.

The focus of this paper is the method for generating uncertainty variables. Combined discrete-event continuous simulation modeling, as well as CPM to SLAMSYSTEM conversion are covered elsewhere (see for e.g. Pritsker et al. 1989).

WEATHER GENERATION MODEL

Generation of weather variables should reflect observed patterns for the region in which the project under study will occur. Stochastic relationships that underlie the basic meteorological processes such as day to day temperature correlation or maximum and minimum temperature correlation on the same day and from day to day are determined for the region to satisfy this requirement. Weather variables of interest in construction simulation are those that affect productivity or may cause stoppage of work. This model generates precipitation, daily maximum temperature, and daily minimum temperature. Other variables (e.g., wind speed) can be generated by obtaining historical data records and following the same procedure.

The weather generation scheme considered is a modification of the process described by Richardson (1981) in which a historical data set is analyzed to determine the stochastic

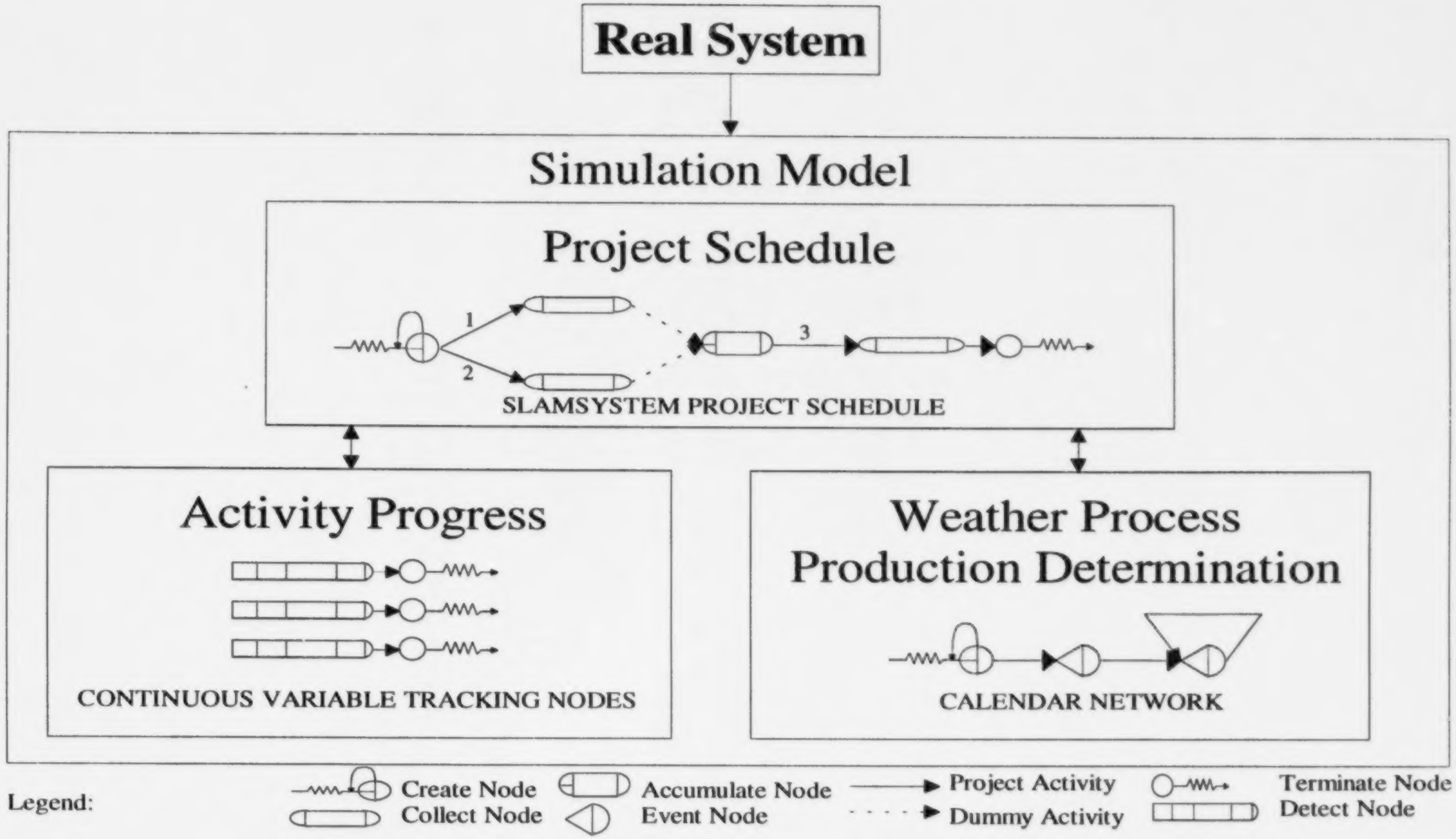

Figure 3-1 Modeling Concepts

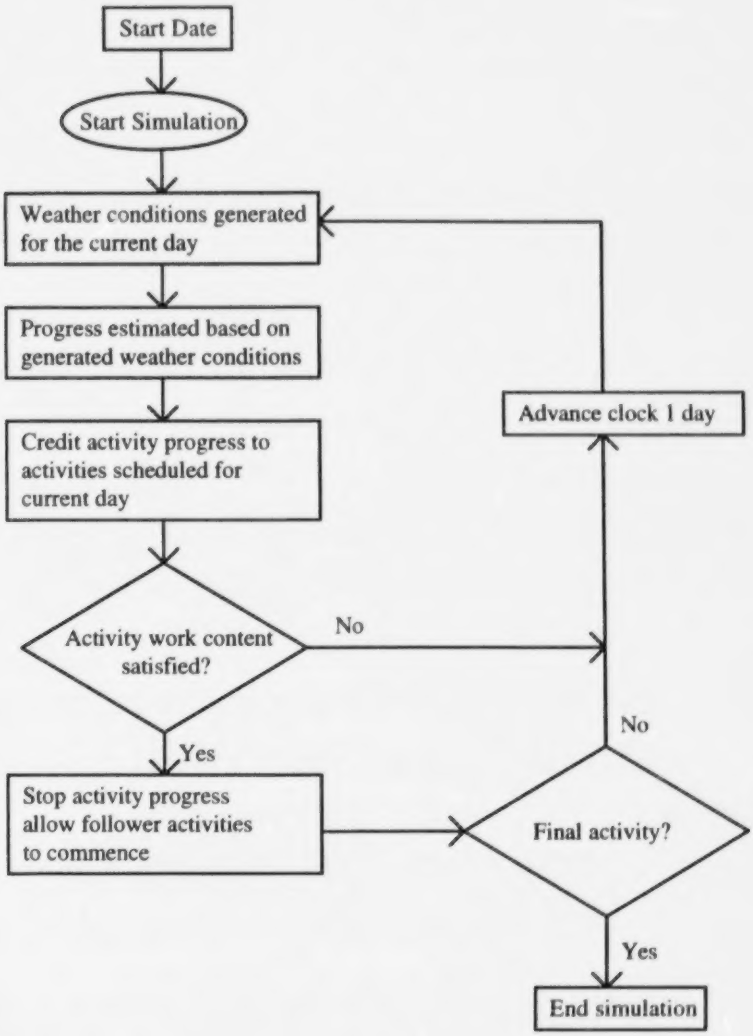
Start Date
Start Simulation
Weather conditions generated for the current day
Progress estimated based on generated weather conditions
Credit activity progress to activities scheduled for current day
Activity work content satisfied?
No
Yes
Stop activity progress allow follower activities to commence
Advance clock 1 day
No
Final activity?
Yes
End simulation

Figure 3-2 Model Flowchart

structure of the meteorological process which is then used to generate weather variables for future dates. The approach considers precipitation as the primary variable and conditions the other variables to the wet or dry status of each day.

Modeling of precipitation events can be accomplished through many procedures. Smith and Hancher (1989) presented a Markov process that is appropriate for prediction of precipitation events. Katz (1985) and Kavvas et al. (1977) have shown that first-order

Markov chains are successful in meteorological applications. For these reasons, the Markov process is selected for modeling precipitation events in this work. Specifically, a two-state (wet, dry) first-order Markov chain, as shown in Figure 3-3 is used where a wet day is defined as a day in which 0.2 mm or more precipitation has fallen. Minor rainfall events have little effect on construction operations and thus are not classified as wet days. Transitional probabilities are determined based on historical time series records of precipitation for each month of the year to reflect seasonality. The Markov chain operates by considering the status of the present day and determining the following day's status based on transitional probabilities of changing from state to state.

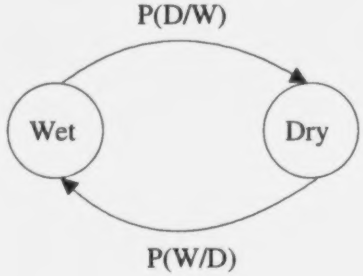

Figure 3-3 Markov Chain for Precipitation States

In the event of a wet day a precipitation amount must be determined. This is done by randomly sampling an amount from a probability distribution fit to historical records. A two parameter gamma distribution is used to describe the occurrence of precipitation amounts. Seasonality of precipitation amounts is captured by calculating separate parameters for the gamma distribution for each month of the year. For example, in Alberta precipitation amounts in June are much higher than those in October. During the project simulation experiment, the calendar date is maintained and therefore the appropriate distribution is sampled.

Generation of maximum and minimum temperatures utilizes the weakly stationary generating process suggested by Matalas (1967). This is a stochastic process which maintains dependencies between weather variables on the same day and from day to day.

Generating weather variables in this manner requires analysis of historical weather data to determine time dependence and interdependence structures.

The first stage in the analysis procedure involves reduction of historical weather data series into residual elements. This is a procedure for normalizing time series data by removing period means and standard deviations of the weather variables (Yevjevich 1972). This is done by: 1) calculating daily means and standard deviations of the historical data set based on the precipitation status of the day (i.e. one mean for dry days and one mean for wet days, likewise for standard deviations); 2) smoothing the daily means and standard deviation series to obtain periodic means and standard deviations; and 3) removing the periodic means and standard deviations from actual values to obtain a time series of residual elements.

Figure 3-4a is a plot of mean daily maximum temperatures in which the day was dry. This data is smoothed to obtain the periodic mean value of maximum temperature for dry days. Richardson (1981) utilizes a Fourier series to perform the smoothing function. In replacement of a Fourier series a general regression neural network (GRNN) is used in this work (Ward Systems Group 1991). A GRNN was found to be easier to implement. It consisted of a one pass training session to determine the network parameters. Once this was achieved the network structure can be easily coded into the simulation model providing accurate predictions comparable to those from Fourier series analysis. Figure 3-4b illustrates the same process for determining periodic standard deviations for dry days.

Periodic means and standard deviations are now removed from the actual weather time series to determine residual elements. Figure 3-5a shows a sample of actual daily maximum temperatures recorded in Alberta in 1991 (Monthly Record). Also, shown is the periodic mean maximum temperature function for dry days and wet days determined in the preceding step. Figure 3-5b is a plot of maximum temperature standard deviations for dry days and for wet days. Residual elements in Figure 3-5c are determined by subtracting the periodic mean maximum temperature and dividing by the periodic standard deviation based on the precipitation status of the day. The result is a time series of residual elements of maximum temperature for the year 1991. This process is repeated for daily minimum temperatures and all years of the historical data set.

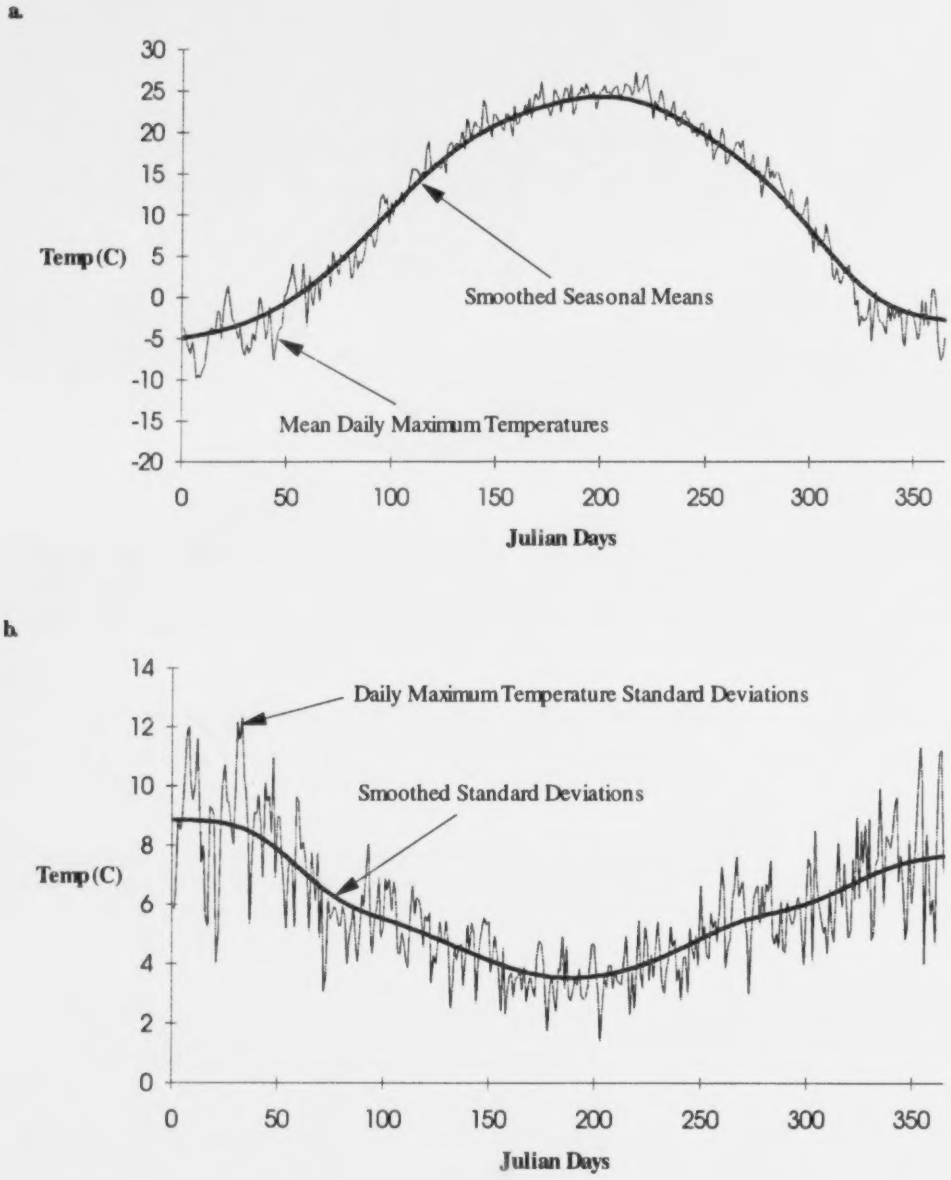

Figure 3-4 Maximum Temperature Means and Standard Deviations (Dry Days)

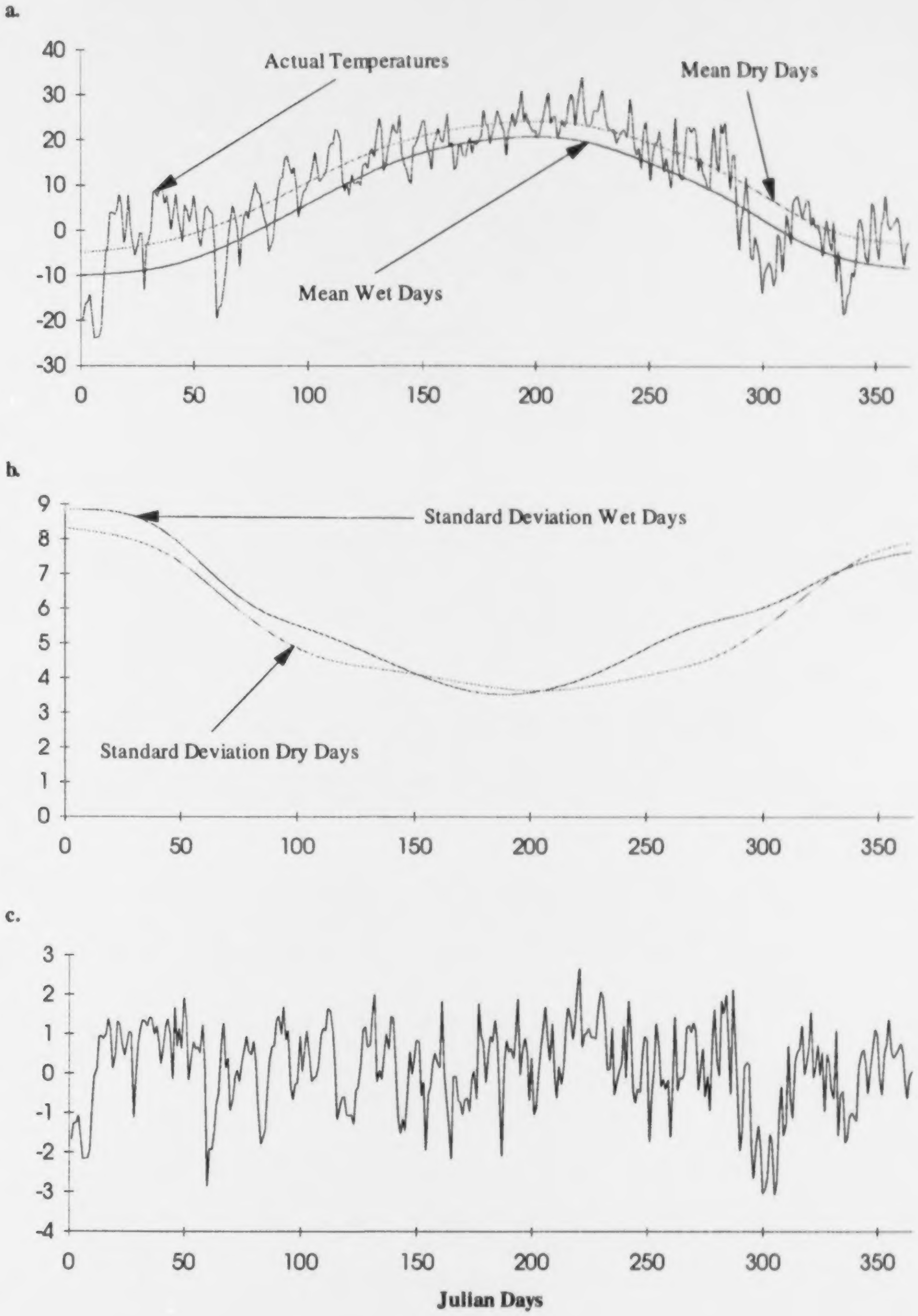

Figure 3-5 Maximum Temperature Residual Series (1991)

The second stage involves analyzing the residual element time series to determine time dependence within each series and interdependence among each series. To do this we calculate cross correlation coefficients between residual series elements on the same day, serial correlation coefficients within each individual series from day to day, and cross correlation coefficients between series elements from day to day. These coefficients define matrices which are used in the weakly stationary generating process to maintain the historical weather patterns.

Stochastic generation of weather variables proceeds using the weakly stationary generating process. In this process new residuals are determined by advancing the current residuals one day through a mapping procedure involving the correlation matrices and adding a random component. Actual weather parameter values are determined by replacing the periodic mean and standard deviation based on the generated precipitation status of the day.

Mathematical procedures defining the weather variable generation process, tests of underlying assumptions, and testing of results can be found in Appendix B. The model was tested by generating 10 years of weather data and comparing to 20 years of historical weather data from the Edmonton Municipal Airport weather station. In almost all instances, generated weather was agreeable to historical weather data.

Generating daily weather variables during a simulation study follows the procedure depicted in Figure 3-6. At the start of the simulation initial precipitation status is determined by generating a uniform random number on the interval 0 to 1. If the number generated is less than or equal to the probability of the day being wet, P(W), for the current month then day 1 of the simulation study is classified as wet (i.e. 0.2 mm or more precipitation) otherwise, the day is considered dry. In the event of a wet day, precipitation amount is determined by generating another uniform random number on the interval 0 to 1 and transforming to a gamma variate defined for the current month. Next, for the first day of a simulation study residuals from the previous day must be determined. The residuals

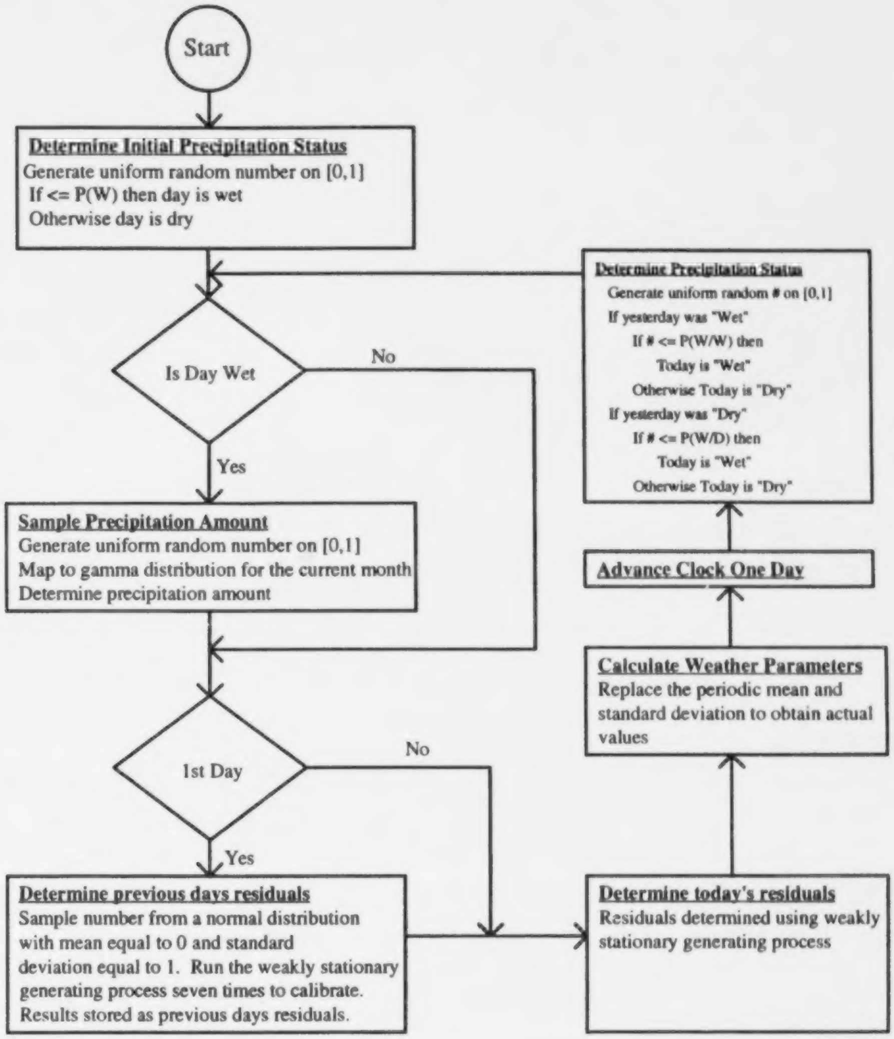
Start
Determine Initial Precipitation Status
Generate uniform random number on [0,1]
If <= P(W) then day is wet
Otherwise day is dry
Is Day Wet
No
Yes
Sample Precipitation Amount
Generate uniform random number on [0,1]
Map to gamma distribution for the current month
Determine precipitation amount
1st Day
No
Yes
Determine previous days residuals
Sample number from a normal distribution with mean equal to 0 and standard deviation equal to 1. Run the weakly stationary generating process seven times to calibrate. Results stored as previous days residuals.
Determine today's residuals
Residuals determined using weakly stationary generating process
Calculate Weather Parameters
Replace the periodic mean and standard deviation to obtain actual values
Advance Clock One Day
Determine Precipitation Status
Generate uniform random # on [0,1]
If yesterday was "Wet"
If # <= P(W/W) then
Today is "Wet"
Otherwise Today is "Dry"
If yesterday was "Dry"
If # <= P(W/D) then
Today is "Wet"
Otherwise Today is "Dry"

Figure 3-6 Weather Generation Flowchart

are sampled from a normal distribution with a mean of zero (0) and a variance of one (1). On the first run the weakly stationary generating process is executed 7 times to initialize the weather generating model. This reduces transitional startup problems that occur at the start of the generating procedure. Today's residuals are determined from the weakly stationary generating process described in the previous section. From the generated residuals actual values are determined by multiplying the residual by the periodic standard deviation and adding the periodic mean. At this point, activity production is determined based on the generated parameters and activity progress is evaluated. The simulation clock is advanced by one day and precipitation status is determined for the current day using the transitional probabilities. This cycle is repeated until the project is completed.

SAMPLE APPLICATION

Simulation of a 3 span steel girder bridge construction is performed to illustrate the model presented in this paper. The scope of work on this project includes: structural excavation and backfill; placing pipe piling; construction of two abutments and two piers; construction of concrete deck and curbs; rip-rap placement; bridge deck waterproofing; placing asphalt wearing surface; installing bridgerail and guardrail posts; miscellaneous iron; service ducts; and painting of the pier steel. This project is expected to start as of June 1, 1994 and is located in the Edmonton region.

A CPM schedule of the project consists of 37 activities as listed in Table 3-1. The schedule is based on 10 hour work days, with no provisions for time off for holidays and weekends. Scheduling calculations performed using Microsoft Project (Microsoft 1992) revealed that the project will require 111 days of production and will be completed on September 19, 1994.

Prior to simulation, weather sensitive activities must be identified by the modeler. For this application activities are classified into separate groups on the basis of similar influencing factors and degree of impact. This is done so that a separate neural network is not required for each individual activity. Productivity for each group of activities is forecast using a neural network trained on productivity data obtained for the particular activities that make up each class. Weather sensitive activities for this application are indicated in column 8 of Table 3-1 by identifying the group to which the activity belongs. For this project the activities were classified into five groups: concreting (i), earthwork (ii), paving and waterproofing (iii), steel erection (iv), and general labor activities (v). Activities considered non-weather sensitive are indicated by "n/s". Formwork stripping operations were not considered weather sensitive activities as it was felt that they would

ID	Activity	Dur.	Date		Sequential Day		Weather Sensitive
			Start	Finish	Start	Finish	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Mobilize	1d	6/1/94	6/1/94	1	1	n/s
2	Layout	2d	6/2/94	6/3/94	2	3	v
3	Excavate Abut #1	2d	6/4/94	6/5/94	4	5	ii
4	Excavate Abut #2	2d	6/6/94	6/7/94	6	7	ii
5	Site Preparation	5d	6/4/94	6/8/94	4	8	ii
6	Piles Abut #1	6d	6/6/94	6/11/94	6	11	n/s
7	Piles Piers #1 & #2	3d	6/12/94	6/14/94	12	14	n/s
8	Piles Abut #2	6d	6/15/94	6/20/94	15	20	n/s
9	Install Pier Web	3d	6/15/94	6/17/94	15	17	iv
10	Concrete Fill Piles	4d	6/21/94	6/24/94	21	24	i
11	Abut #1 Seats FRP	5d	6/25/94	6/29/94	25	29	i
12	Abut #1 Seats Strip	1d	7/3/94	7/3/94	33	33	n/s
13	Abut #1 BW & WW FRP	5d	7/4/94	7/8/94	34	38	i
14	Abut #1 BW & WW Strip	1d	7/12/94	7/12/94	42	42	n/s
15	Abut #2 Seats FRP	5d	7/4/94	7/8/94	34	38	i
16	Abut #2 Seats Strip	1d	7/12/94	7/12/94	42	42	n/s
17	Abut #2 BW & WW FRP	5d	7/13/94	7/17/94	43	47	i
18	Abut #2 BW & WW Strip	1d	7/21/94	7/21/94	51	51	n/s
19	Pier #1 Caps FRP	5d	6/25/94	6/29/94	25	29	i
20	Pier #1 Caps Strip	1d	7/3/94	7/3/94	33	33	n/s
21	Pier #2 Caps FRP	5d	6/25/94	6/29/94	25	29	i
22	Pier #2 Caps Strip	1d	7/3/94	7/3/94	33	33	n/s
23	Erect Steel	10d	7/26/94	8/4/94	56	65	iv
24	Deck FRP	15d	8/5/94	8/19/94	66	80	i
25	Deck Strip	5d	8/23/94	8/27/94	84	88	i
26	Miscellaneous Iron	4d	8/30/94	9/2/94	91	94	iv
27	Curbs & Duct FRP	5d	8/20/94	8/24/94	81	85	i
28	Curbs & Duct Strip	2d	8/28/94	8/29/94	89	90	n/s
29	Backfill & Compact	4d	7/22/94	7/25/94	52	55	ii
30	Approach Slabs	4d	7/26/94	7/29/94	56	59	iii
31	Handrail & Posts	6d	8/30/94	9/4/94	91	96	iv
32	Waterproof Deck	7d	9/8/94	9/14/94	100	106	iii
33	Pave Deck	3d	9/15/94	9/17/94	107	109	iii
34	Painting	5d	7/4/94	7/8/94	34	38	iii
35	Rip Rap	16d	6/9/94	9/24/94	9	24	n/s
36	Patch Exp. Concrete	23d	7/4/94	7/26/94	34	56	n/s
37	Clean Up-Move Out	2d	9/18/94	9/19/94	110	111	v

Table 3-1 Bridge Activities and CPM Schedule

be delayed only in extreme weather conditions. Rip-rap placement, and patching exposed concrete are excluded since these activities are performed throughout the duration of the project and can be executed at a time when conditions are favorable and thus will not impact the project schedule. Piling operations are not included as weather sensitive as we felt weather would have little influence on this operation. All other activities were expected to be sensitive to the effects of weather and are included as such.

Productivity is predicted based on generated weather conditions using neural networks trained on existing productivity data. The networks produce a productivity value when given the weather conditions for the day. Productivity values are the production achieved on a given day under specified conditions divided by the assumed production for an activity (e.g. the productivity value used to originally estimate the activity duration). Therefore, productivity values can be greater than or less than 1 depending on whether production was better than or less than the assumed proudctivity on a particular day.

For each category of weather sensitive activities a separate neural network similar to the network shown in Figure 3-7 is trained with historical data to determine daily productivity based on generated weather conditions. The network shown in Figure 3-7 is the network used for predicting productivity of earthwork operations. For this example the following assumption were made: concreting activities are affected by maximum and minimum temperatures; earthwork operations are most sensitive to precipitation and low temperatures; steel erection is largely influenced by daily temperatures; paving and waterproofing can not proceed at temperatures below freezing or in precipitation; and general labor activities are affected by temperature and precipitation. Other factors impact these types of activities, however, for this work we are limited to these variables. A separate neural network is developed and trained to predict productivity for each category.

A simulation model of the project schedule is constructed using a computer program which automatically converts an existing CPM network into the required SLAMSYSTEM simulation code. A section of the simulation model is illustrated in Figure 3-8. The model consists of 3 main components: the project network; detect nodes; and a calendar network. The project network maintains the logic of the project schedule (i.e. CPM

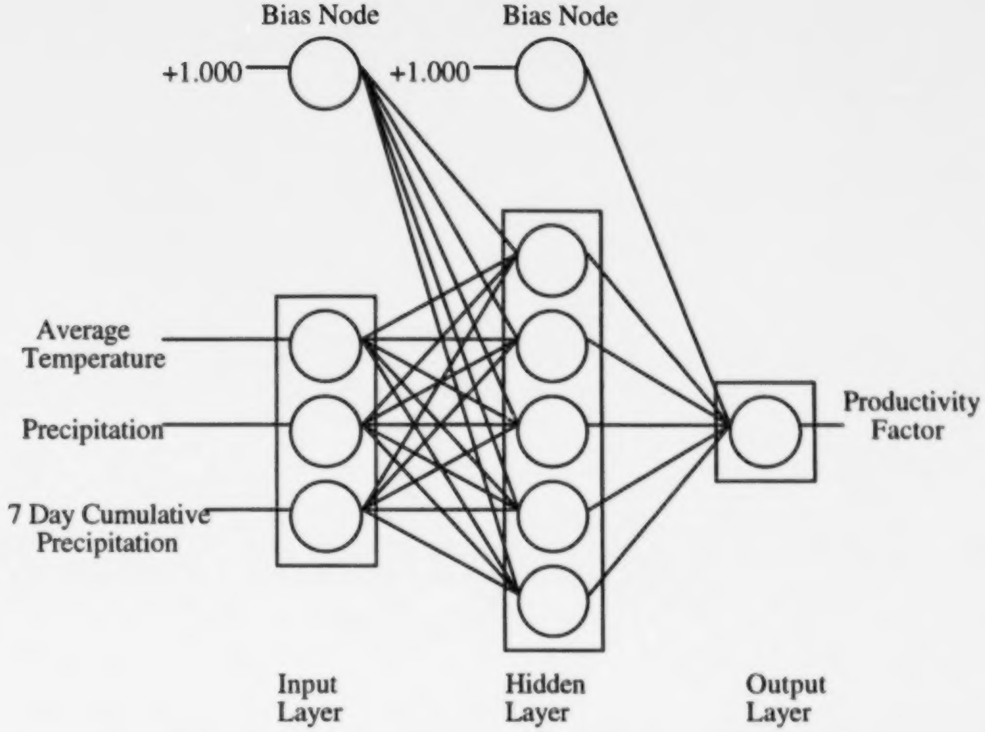

Figure 3-7 Earthwork Productivity Neural Network

structure), detect nodes track the values of continuous variables and determine the time when weather sensitive activities are complete; and the calendar network controls the simulation of weather variables. At the start of a simulation run two events occur; weather parameters for the day are generated, and starting activities in the project are initiated. The first activity in this model is not sensitive to weather, therefore, simulated time is incremented by one day. This coincides with the end of Activity 1, statistics are collected on the completion time of Activity 1 and Activity 2 commences. Activity 2 is a weather sensitive activity therefore its final duration is not known at this time. At the start of day 2 weather parameters are generated and a productivity value is determined using a neural network similar to the one shown in Figure 3-7. The network determines the productivity value for the current activity. In this case a value of 1.45 is determined. Detect node "END2" credits the progress of Activity 2 with 1.45 days of progress. The

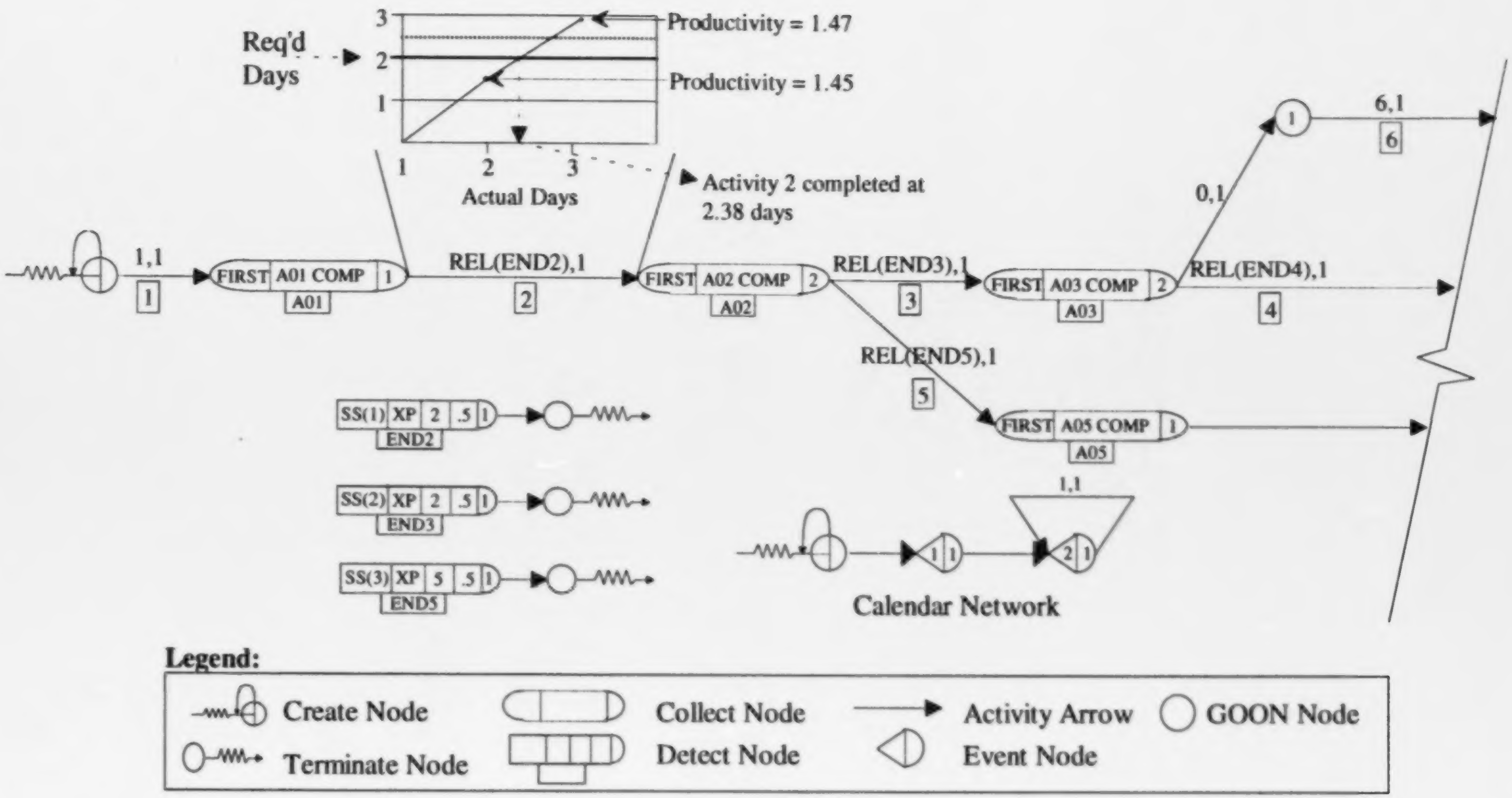

Figure 3-8 Project Simulation Model

simulation clock now advances to day 3 and new weather conditions are generated and a new productivity value determined. Weather conditions on day 3 result in a productivity value of 1.47. Activity progress is credited with an additional 1.47 days of progress in detect node "END2". Activity 2 progress is now 2.92 while the required progress for completion is only 2 days. The detect node specifies a tolerance value of 0.5 which means that a crossing of the 2 day threshold value must occur within 0.5 days (i.e. 2.5 days or less). Since this did not occur the step size is reduced until this tolerance is met. In this case the step size is reduced to 0.38 and a value of 2.01 days of activity progress is obtained and Activity 2 is complete as of day 2.38. Statistics are collected and activities 3 and 5 are started at day 2.38 of the schedule. This process continues until the project is completed.

Simulation of the project schedule is performed a number of times in order to have a representative sample of possible project schedules and determine confidence intervals for specified project completion times. Results of the 30 run simulation experiment are presented in Table 3-2.

It is also desirable to determine the effect of varying the start date of the project. Project completion times for several start dates are shown in Table 3-3. Results illustrate the sensitivity of the project schedule to the seasonal weather conditions that will be encountered due to different start dates. April, May, June, or July start dates result in expected project completion times between 103 and 109 days. These estimates show minor variation reflected by the low values obtained for standard deviations and a tight range of possible project completion times. An August start date results in a significant increase in the mean project duration as well as a large increase in the standard deviation indicating a high degree of variability in the project completion time estimate. The range of sample project completion times has increased to 99 days as compared to 15 days with a July 1st start date. The situation gets progressively worse with a September 1st start date as revealed by the increase in mean duration from 138 days to 172 days, a larger standard deviation, and a range of 112 days. It is evident that the onset of winter weather in a cold climate like Alberta causes significant delay and variability in the project schedule.

ID (1)	Name (2)	Mean Duration (3)	Mean Start Date (4)	Mean Start Day (5)	Mean Finish Day (6)
1	Mobilize	1d	1/6/94	1	1
2	Layout	1.5d	2/6/94	1	2.5
3	Excavate Abut #1	3.1d	3/6/94	2.5	5.6
4	Excavate Abut #2	2.4d	6/6/94	5.6	8.0
5	Site Preparation	6.6d	3/6/94	2.5	9.1
6	Piles Abut #1	6d	6/6/94	5.6	11.6
7	Piles Piers #1 & #2	3d	6/12/94	11.6	14.6
8	Piles Abut #2	6d	6/15/94	14.6	20.6
9	Install Pier Web	2.4d	6/15/94	14.6	17.0
10	Concrete Fill Piles	3.2d	6/21/94	20.6	23.8
11	Abut #1 Seats FRP	4.6d	6/24/94	23.8	28.4
12	Abut #1 Seats Strip	1d	7/2/94	31.4	32.4
13	Abut #1 BW & WW FRP	4.2d	7/3/94	32.4	36.6
14	Abut #1 BW & WW Strip	1d	7/10/94	39.6	40.6
15	Abut #2 Seats FRP	4.2d	7/3/94	32.4	36.6
16	Abut #2 Seats Strip	1d	7/10/94	39.6	40.6
17	Abut #2 BW & WW FRP	4.3d	7/11/94	40.6	44.9
18	Abut #2 BW & WW Strip	1d	7/18/94	47.9	48.9
19	Pier #1 Caps FRP	4.6d	6/24/94	23.8	28.4
20	Pier #1 Caps Strip	1d	7/2/94	31.4	32.4
21	Pier #2 Caps FRP	4.6d	6/24/94	23.8	28.4
22	Pier #2 Caps Strip	1d	7/2/94	31.4	32.4
23	Erect Steel	9.1d	7/24/94	53.6	62.7
24	Deck FRP	12.6d	8/2/94	62.7	75.3
25	Deck Strip	4.3d	8/18/94	78.3	82.6
26	Miscellaneous Iron	3.1d	8/24/94	84.6	87.7
27	Curbs & Duct FRP	4.3d	8/15/94	75.3	79.6
28	Curbs & Duct Strip	2d	8/22/94	82.6	84.6
29	Backfill & Compact	4.7d	7/19/94	48.9	53.6
30	Approach Slabs	7.9d	7/24/94	53.6	61.5
31	Handrail & Posts	4.9d	8/24/94	84.6	89.5
32	Waterproof Deck	9.4d	9/2/94	93.6	103.0
33	Pave Deck	3.0d	9/12/94	103.0	106.0
34	Painting	8.9d	7/3/94	32.4	41.3
35	Rip Rap	16d	6/10/94	9.1	25.1
36	Patching Exposed Concrete	23d	7/3/94	32.4	55.4
37	Clean Up & Move Out	3.0d	9/15/94	106.0	9/17/94(109)

Table 3-2 Mean Simulation Results

Start Date (1)	Mean Duration (days) (2)	Standard Deviation (3)	Minimum Duration (4)	Maximum Duration (5)
April 1, 1994	106	5.27	97	122
May 1, 1994	109	4.71	100	120
June 1, 1994	109	4.14	101	118
July 1, 1994	103	4.09	97	112
August 1, 1994	138	27.0	99	198
September 1, 1994	172	32.6	103	215

Table 3-3 Effect of Change in Start Date

CONCLUSIONS

Construction simulation is often performed using MicroCYCLONE (Halpin 1990) however, continuous modeling procedures are not supported in MicroCYCLONE at this time. Therefore, it was necessary to use a general purpose simulation language which provided this feature. SLAMSYSTEM provided the necessary modeling capabilities and was therefore used to illustrate the concepts.

Project planning can be enhanced using this approach by planning for weather protection if the analysis reveals that weather will cause delays or planning around the occurrence of bad weather. A further application is in the field of claims analysis. Specifically, claims involving delayed start dates can be analyzed in this manner. It can be shown that delaying the start date by 1 month in April, May or June has little impact on the project schedule, however, if a delay causes the project to start August 1 rather than July 1 then significant impacts are observed in the project schedule and the contractor may be entitled to compensation depending on the cause of the delay.

The model presented in this paper illustrates a method for generating the occurrence of weather variables, determining the impact on productivity, and modifying activity duration in accordance with the determined impact. The overall process is controlled by the SLAMSYSTEM while weather generation and neural network productivity forecasting is executed in user written FORTRAN code. Therefore, the model can be easily adapted to generate other continuous stochastic processes affecting productivity. The neural networks can also be adapted to determine productivity based on several factors. Therefore, this model can be used as a framework for future research in this area.

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CHAPTER 4: MODELING CONSTRUCTION PRODUCTIVITY FOR COMPUTER SIMULATION[1]

INTRODUCTION

Construction labor and equipment productivity vary in accordance with many uncertain factors. Environmental site conditions such as temperature, relative humidity, wind speed, and precipitation dramatically impact productivity. These conditions vary according to continuous random stochastic processes. Therefore, estimating project milestones and completion times involve some degree of uncertainty depending on time of year, location, and weather protection provided. Determining risk associated with estimated milestone and completion times, critical activities and those likely to become critical, and sensitivity of activities to specific variables assists project management personnel by enabling them to identify the need for schedule revision in the planning stage, determine a realistic schedule, establish the pace of construction, devote more time and effort to critical activities and those likely to become critical, and identify potential delays and take timely corrective action.

Simulation is a tool useful for analyzing project schedules. Accurate simulation results depend on a realistic model of the project schedule and the actual construction environment. Project simulation often involves a network model of the project schedule and activity duration estimates sampled from statistical distributions reflecting the modeler's uncertainty about the duration of activities as well as inherent variability in the time required to perform repetitions of activities (AbouRizk et.al. 1991). Improved simulation results are possible by generating the expected occurrence of uncertainty factors causing variation in productivity, explicitly analyzing and quantifying the combined impact, and incorporating it in the activity duration estimates (Ahuja and Nandakumar 1985). Although the second approach is much more difficult to implement, improved simulation results are possible by executing accurate uncertainty factor generation and impact quantification. Advantages of this approach are that time of year and project location is inherent in the model architecture thus eliminating the need to adjust activity duration distributions to reflect these factors.

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[1] A version of this chapter has been submitted for publication. ASCE, Computing in Civil Engineering.

A project simulation model that generates the occurrence of factors affecting construction productivity, determines impact on productivity, and produces probabilistic time estimates of project milestones and completion time is the objective of this research. The objective is achieved by integrating several existing software packages that operate in the Microsoft Windows (Microsoft Corporation 1992) environment. SLAMSYSTEM (Pritsker Corporation 1990), a Windows based simulation software, controls project simulation. A model of the project on which simulation can be performed is generated from an existing project CPM network by a computer program written by the authors in the Microsoft Visual Basic (Microsoft Corporation 1993) programming system (see Appendix A). Determining productivity during simulation is achieved using NeuroWindows (Ward Systems Group 1991), a neural network dynamic link library for Visual Basic. All of the software used in the development of the project simulation model can be readily integrated since they operate in the Windows environment. This paper presents the productivity component of the project simulation model.

Organization of the paper is as follows. The following section describes the project simulation model satisfying the stated objectives of this paper, reviews existing productivity forecasting methods based on the occurrence of various factors impacting productivity, and presents an alternative productivity forecasting method featuring artificial intelligence. The next section provides a general description of neural networks, explains network training methods, and describes incorporation of the neural network into the simulation model. The third section provides an example from a project simulation study to illustrate the process. The paper concludes by highlighting advantages of neural network productivity forecasting in simulation models, identifying some enhancements, discussing software integration, and outlining future research directions.

BACKGROUND

A schedule simulation model that satisfies the objectives set forth in the preceding section was developed in SLAMSYSTEM. Other general purpose simulation languages with similar features may also be used to implement the model. It was necessary to utilize the combined discrete-event continuous simulation features of SLAMSYSTEM to accomplish the stated objectives. A schematic diagram of the project simulation model appears in Figure 4-1. It consists of three components: 1) a project network that maintains schedule logic; 2) a component that generates uncertainty factors based on stochastic models capturing arrival processes of uncertainty factors; and 3) a productivity model relating uncertainty factors to productivity under generated project conditions. In this work, weather is modeled due to its large impact on construction productivity and inherent complexity. Successful modeling of weather and its impact on productivity will show that other factors can be included in a similar manner.

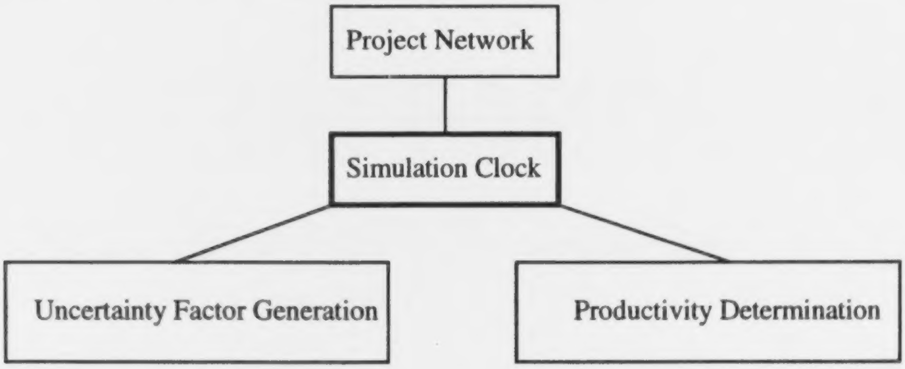
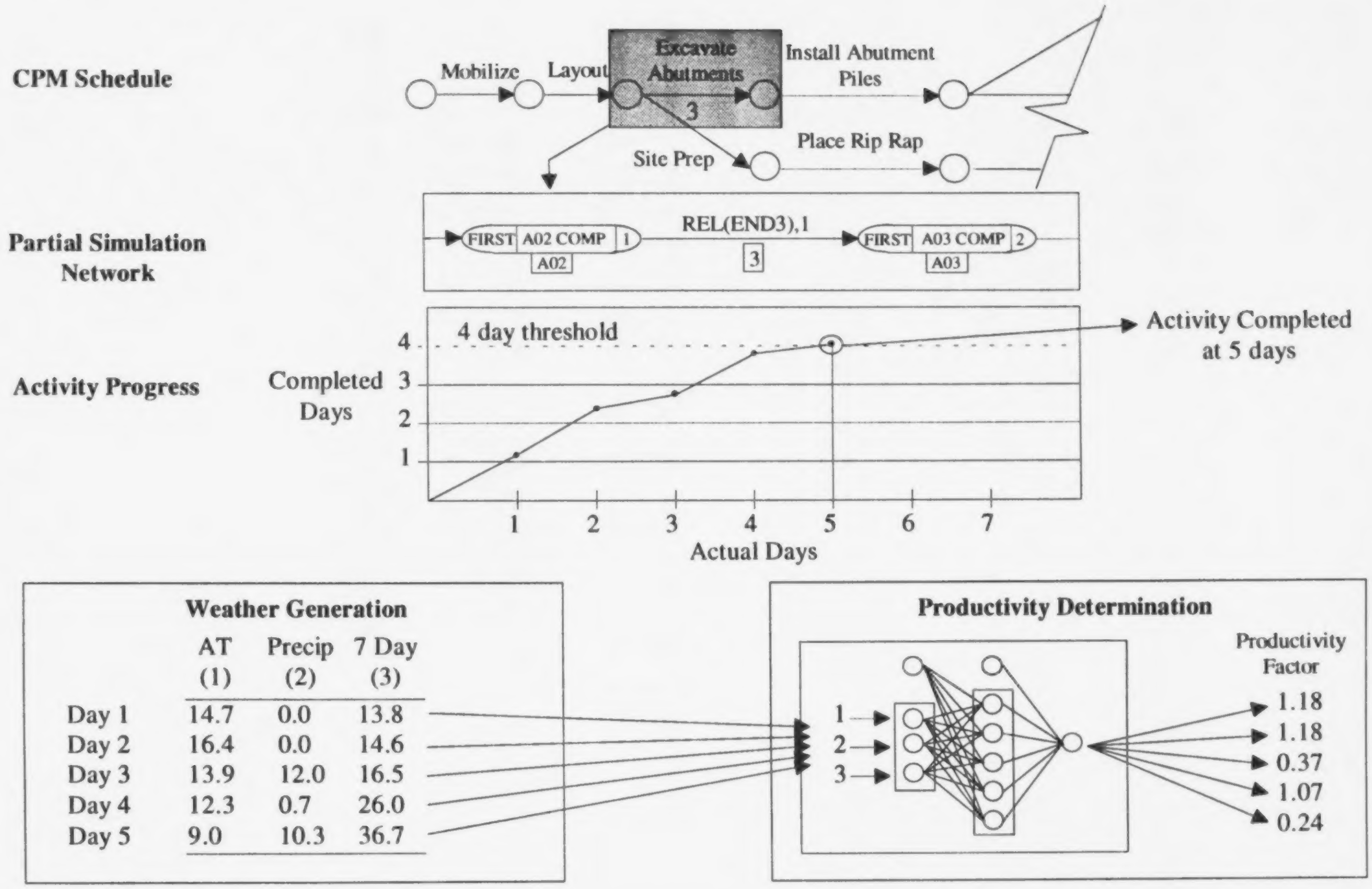


Figure 4-1 Simulation Model Schematic

Combined discrete-event continuous simulation is a clock driven process where time is incremented in equal steps and the other three components respond to clock events. Figure 4-2 illustrates the event sequence during simulation. A CPM schedule for a bridge project appears at the top of Figure 4-2. Enlargement of Activity 3, excavate abutments,



	AT (1)	Precip (2)	7 Day (3)
Day 1	14.7	0.0	13.8
Day 2	16.4	0.0	14.6
Day 3	13.9	12.0	16.5
Day 4	12.3	0.7	26.0
Day 5	9.0	10.3	36.7

Figure 4-2 Project Simulation Model

illustrates a partial component of the simulation network schedule. An arrow surrounded by two nodes labeled "A02" and "A03" represents Activity 3. Collection of statistics for the completion time of Activity 2 occurs at node "A02"; node "A03" performs the same function for Activity 3. "REL(END3)", a SLAMSYSTEM function used to trace activity progress by continuous variables, controls the duration of Activity 3. Simulation of Activity 3 proceeds as follows:

- generating weather conditions for day 1,
- determining the productivity factor, and
- updating activity progress.

The procedure continues by advancing the simulation clock to day 2 and then repeating the process. At day 5, completion of Activity 3 occurs by crossing the threshold completion time (4 days). Based on the assumed productivity used to estimate the duration of Activity 3, 4 days are required to complete the activity. However, in this case a completion time of 5 days is observed. This is due to slightly unfavorable weather conditions. This sequence of events occurs for all other activities in the order specified by the project network. Completion of the final activity signals the end of the project.

Weather generation uses a continuous random stochastic model based on historical records for the project location (see Chapter 3). A model relating weather to productivity determines a productivity factor. Productivity in this paper is defined as follows:

$$\text{Productivity Factor} = \frac{\text{Achieved Productivity}}{\text{Assumed Productivity}} \quad \text{.........} \quad (1)$$

The reason for choosing this definition will become evident later in the paper. Determining productivity based on generated weather conditions is a very important aspect of this simulation methodology. Accurate simulation results depend on correct determination of productivity factors given specified weather conditions. Therefore, this topic requires considerable attention in this work.

Many statistical regression models relating productivity to project conditions are available in the literature. Sanders and Thomas (1993) developed a statistical model to forecast the productivity of masonry activities based on factors identified as having the greatest impact on productivity (i.e work type, building element, design requirements, construction methods, weather, and crew size). Koehn and Brown (1985) developed equations relating overall construction productivity to temperature and relative humidity for activities involving excavation (manual), erection, masonry, electrical, carpentry, laborers, and excavation (equipment). The National Electrical Contractors Association (1974) studied the effect of temperature on productivity of electricians. The following reasons prompted us not to implement any of the above models:

- many are specific to individual crafts and construction techniques. In order to simulate entire projects we require models that can predict productivity for all types of activities in a project, not just one or two. The method developed in this research addresses this issue.
- many only relate one or two factors to productivity
- each company has their own specific methods and practices; and updating the models as new data becomes available is cumbersome. Improved confidence in simulation results occurs if the company's own data provides a basis for the productivity model.

This simulation methodology requires a productivity model that is flexible, can be based on historical company data, and facilitates updating when new data becomes available such that the model remains current with present technology and techniques. Our approach takes advantage of the fact that most construction companies maintain their own productivity data, record the conditions for each data point (if not, it may be available from other sources such as weather records), and tend to follow the same practices from job to job. The provided framework allows the modeler to input actual productivity and associated conditions to a self-training model that eventually reflects the pattern observed between input and output values. Neural networks, a branch of artificial intelligence, provide a workable solution to the productivity forecasting module of this research.

MODELING PRODUCTIVITY FOR PROJECT SIMULATION USING NEURAL NETWORKS

Neural networks are computer models designed to learn in a manner similar to that observed in humans. Supervised or unsupervised networks are available where: supervised networks classify patterns, make predictions, and make decisions based on patterns of input and output values that have been "learned", while unsupervised networks classify sets of data into a specified number of categories without learning from other data sets. This research makes use of supervised neural networks trained on productivity data.

The neural network illustrated in Figure 4-3 is used to predict productivity. Three slabs containing individual nodes (neurons) and weighted connections between each slab comprise the network. This particular network is used for predicting productivity for earthwork operations. Input values to the network consist of daily average temperature, precipitation, and cumulative precipitation over the previous seven days. These values are chosen as it was felt that they have a large impact on earthwork operation productivity. By no means are these the only influencing factors, however, they have an impact on earthwork operation productivity. Daily average temperature is significant as the temperature approaches the freezing point and the ground becomes frozen and harder to handle. Precipitation impacts productivity by reducing productivity due to wet soil conditions and eventually stopping work altogether when precipitation is excessive. Cumulative seven day precipitation gives an indication of the soil moisture content which impacts productivity. For example, in a day where there is no precipitation but the previous 3 days were wet then productivity is reduced. This variable accounts for this type of situation. These values enter the input layer, propagate to the hidden layer via weighted connections and propagate to the output layer where the productivity factor is determined. A typical node is shown in Figure 4-3. Propagation from layer to layer

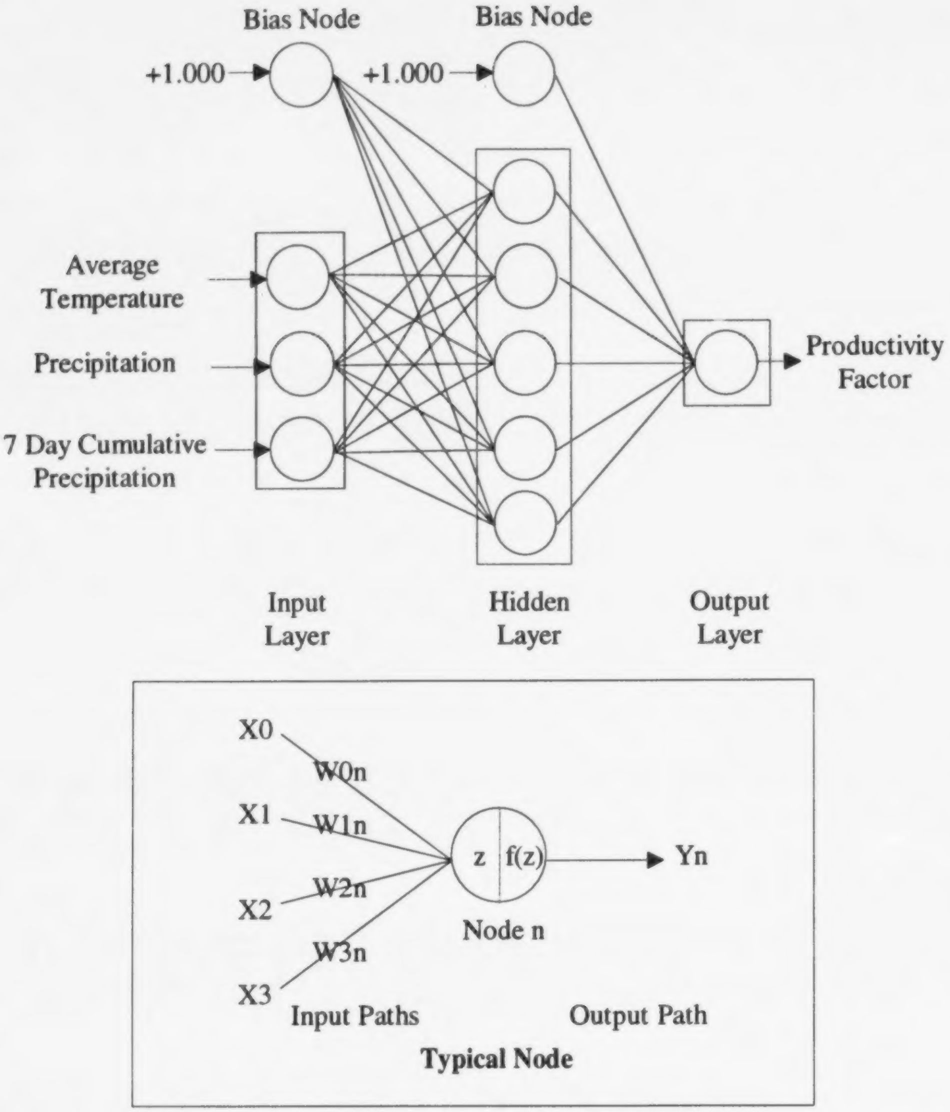


Figure 4-3 Feed Forward Neural Network

occurs by summing the node values from the previous layer multiplied by their respective connection weights to each node as shown in equation (2).

$$z(n) = \sum_{i=1}^{k} X_i W_{in} \quad \dots\dots\dots \quad (2)$$

where k is the number of nodes in the previous layer. The current node value is calculated by applying an activation function to the sum that maps the value to a pre specified range.

$$Y_n = f(z) = \frac{1}{1+e^z} \quad (3)$$

All network nodes function in a similar manner. This activation function is the sigmoid function that maps values to the range zero (0) to one (1). Other activation functions can be used as well. To determine which activation function performs best the modeler can experiment with different ones to determine which provides the best results.

Factors, other than those considered here, impact productivity of earthwork operations. The intention is to illustrate how neural networks can relate input factors to productivity. The input layer can be expanded to including other factors as necessary. Different types of activities are affected by different factors, therefore, it is also necessary to classify activities into groups that are impacted in a similar manner and to the same degree by common factors. A separate neural network can be constructed for each class of activity in order to determine productivity factors rather than constructing a network for each activity.

Training the neural network to produce proper results requires a set of data consisting of inputs and corresponding correct output values. This data is used to "teach" the neural network to deliver the proper output given a set of inputs. Learning occurs by adjusting the weighted connections between the neurons of each slab such that it minimizes the overall error between the predicted and actual output. After many presentations of input patterns and weight adjustments the network should eventually predict the correct output for a given set of input values. Network testing involves presenting data not previously "seen" by the network and comparing predicted output values to actual values to determine network performance.

A sample of earthwork productivity data appears in Figure 4-4. Plotting the data against average daily temperature (Figure 4-4a), daily precipitation (Figure 4-4b), and cumulative precipitation for the previous 7 days (Figure 4-4c), reveals a relationship to each of the factors. Neural networks, by their nature, are excellent tools for handling this

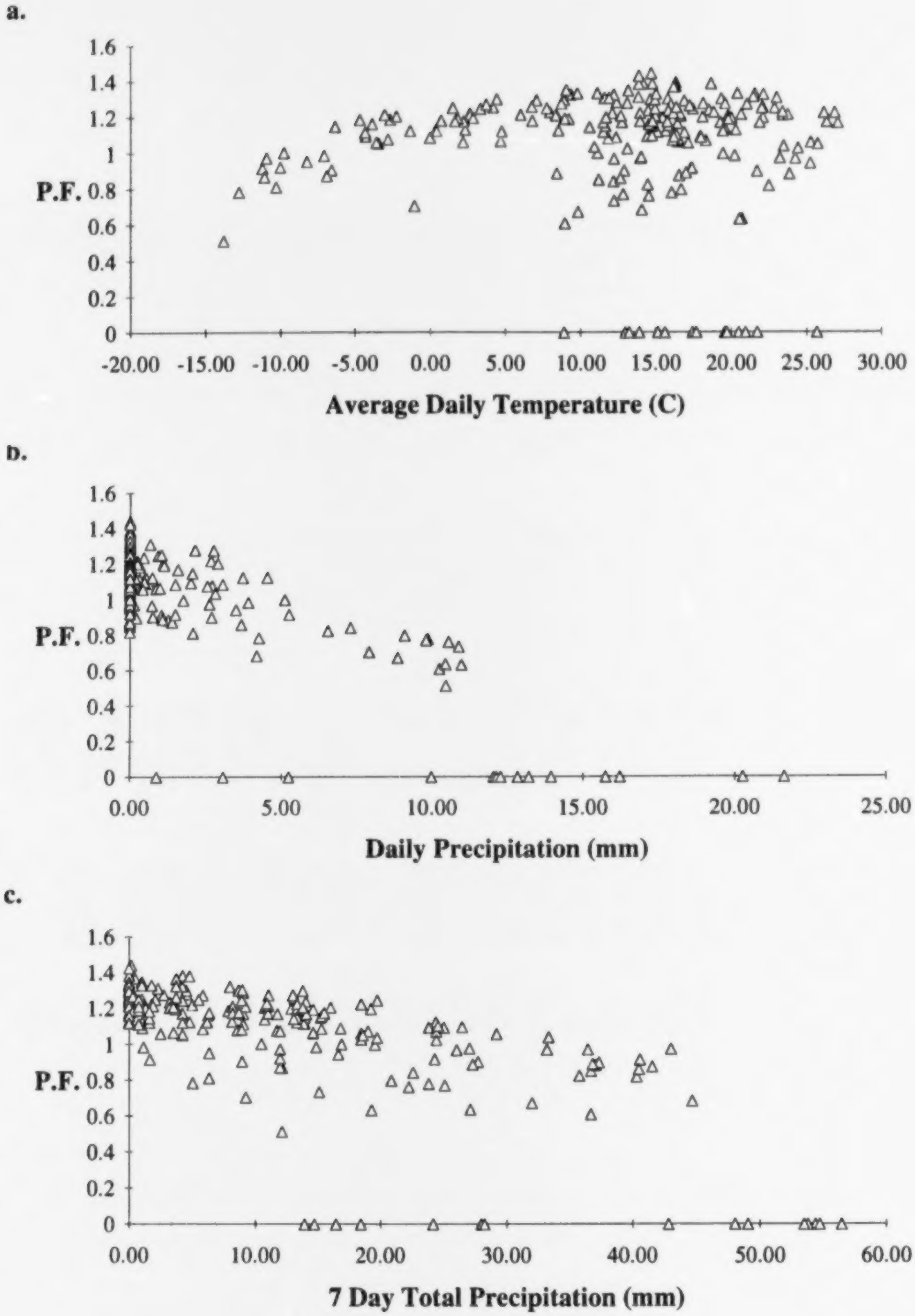


Figure 4-4 Earthwork Productivity vs Various Factors

type of "fuzzy" data. Productivity factors are predicted using the network shown in Figure 4-3. A total of 214 data points are available; half are randomly selected for network training, with testing performed on the remaining points.

During training of the network mean absolute error and maximum error was continually monitored since these values are indicative of network performance. At the point when these values appeared to level off training was stopped and the network tested. Figure 4-5 shows the network predictions plotted against the actual productivity values of the test data set. Visually the network appears to be producing acceptable results. Further analysis of the predicted and actual values revealed a correlation coefficient of 0.94, a mean average error of 0.08, and a maximum error of 0.37. These results are acceptable considering the inherent variability observed in productivity data.

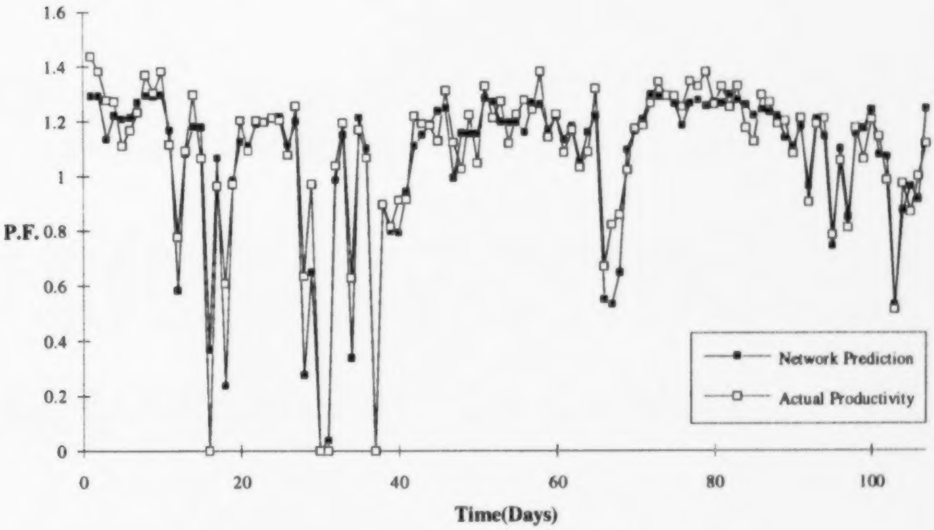


Figure 4-5 Network Predictions vs Actual Productivity Values

During simulation, the trained neural network predicts productivity when supplied with generated weather conditions. Direct incorporation of the neural network algorithm into the simulation model eliminates calls to external programs during simulation. The following example illustrates the entire simulation process and incorporation of neural network predictions.

SAMPLE APPLICATION

To illustrate operation with simulation consider Activity 3 of the bridge construction network of Figure 4-2. Activity 3 involves machine excavation for the bridge abutments. The first step is to determine the estimated completion time for the activity by using an assumed productivity value. The assumed productivity is the productivity value that the estimator uses when estimating the project. It may be a value that the estimator determines from experience or from an estimating value or it may be the average value taken from productivity studies. Assumed productivity is the denominator in the equation (1). The duration of Activity 3 is estimated using the following data.

Volume of earth:	200 m^3
Hours per day:	10 hrs
Machine productivity:	5 m^3/hr

The following calculations indicate that the job should require 4 days to fully complete.

$$\text{Daily Production} = \frac{5\text{m}^3}{\text{hr}} \times \frac{10\text{hr}}{\text{day}} = \frac{50\text{ m}^3}{\text{day}}$$

$$\text{Days Req'd} = \frac{200\text{ m}^3}{\left(\frac{50\text{ m}^3}{\text{day}}\right)} = 4\text{ Days}$$

The basis of this productivity estimate is the assumed productivity value (5 m^3/hr). This value corresponds to a productivity factor of one (1.0). If conditions vary and the productivity value deviates from 5 m^3/hr then the productivity factor will be greater or less than one (1.0) depending on whether productivity is better or less than assumed. For example, if favorable conditions (e.g., no precipitation, high average temperature) lead to increased productivity of 8 m^3/hr then the productivity factor would be 1.6 (i.e., 8/5 =

1.6). The neural network determines productivity factors considering if weather conditions were favorable, average, or unfavorable for the activity being considered.

Simulation of the excavation activity proceeds in the following sequence. The model generates weather conditions for day 1 of the activity and presents them to the neural network input layer. The neural network propagates these values to the output layer, obtains a productivity factor, and evaluates activity progress. Activity 3 productivity values appear in Table 4-1.

Day (1)	**Productivity (2)**	**Activity Progress (3)**	**Required Progress (4)**	**Completed (5)**
1	1.18	1.18	4.0	No
2	1.18	2.36	4.0	No
3	0.37	2.73	4.0	No
4	1.07	3.80	4.0	No
5	0.24	4.04	4.0	Yes

Table 4-1 Activity 3 Progress

Completion of Activity 3 allows the following activity "Install Abutment Piles" to proceed. All weather sensitive activities undergo the same sequence of events in the order specified by the network. Calculation of project completion time occurs upon completion of all activities in the network. Executing many simulation runs generates a range of project milestones and completion times used to determine valuable management information.

CONCLUSIONS

Forecasting productivity with neural networks during simulation studies offers several advantageous features. The approach is simpler in nature than sophisticated multivariate regression analysis that create functions that relate the various input parameters to productivity. Building the network requires little effort on the part of the modeler. He/she must only designate the required number of input nodes and choose an appropriate number of hidden layer nodes to create the neural network forecasting model. Furthermore, neural network enhancements allow the modeler to achieve any desired level of sophistication. Addition of more nodes and layers, use of different learning rates and learning algorithms, and testing various network configurations and types may help achieve the desired results. Customization of neural networks to user provided data to reflect the construction practices and techniques employed within the user's company offers a significant advantage over other available forecasting models. As completed projects provide new data retraining or further training of the network will reflect any changes observed. This way the neural network is always current with the latest productivity data.

Investigating network enhancements may improve the neural network model. Recursive slabs added to the network identify productivity trends such as learning curve effects by capturing trends observed in training data. Including more factors that impact construction productivity such as site congestion, change orders, overtime, and others is possible by expanding the input layer of the neural network.

Future research in neural network productivity forecasting include testing the network performance on real productivity data. Research data for this work is derived from assumed productivity relationships and random components. The point is to illustrate the use of neural networks as a productivity forecasting method. We have shown that the neural network is trainable and gives accurate results for the "fuzzy" data presented in this case.

All of the software used in the development of this model operates in the Microsoft Windows environment. NeuroWindows, SLAMSYSTEM, and the program written to convert a CPM project network into an equivalent SLAMSYSTEM simulation network all operate in the Windows environment. This simplifies the process of integrating these software packages. Integration of the systems would be a very attractive feature and could be used to great advantage. Powerful neural networks could be constructed and automatically incorporated into the simulation model. Furthermore, scheduling data could be entered in Windows based scheduling software such as Microsoft Project (Microsoft

Corporation 1992) and converted directly into a SLAMSYSTEM model. The user would be provided with an interactive environment where the power of several software packages is combined.

Neural networks are very powerful tools and continuing research in this area should lead to accurate productivity forecasting models. Continual advancements in neural network technology will only improve the prospect of using them for productivity forecasting. The method has many advantages over traditional techniques and is easily included in a simulation model. Productivity data has many complex relationships to numerous factors making neural networks the ideal technology to map relationships between uncertainty factors and productivity.

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CHAPTER 5: CONCLUSION

SUMMARY OF THESIS WORK

Accurate schedules are important factors in the success of a construction project. Late projects result in unsatisfied owners, can result in liquidated damages, and delay start dates of future contracts by tying up valuable resources longer than expected. To complete a late project on time requires extra resources that generally come at additional cost thereby affecting a construction company's bottom line (e.g. profit). It is extremely important that realistic predictions are made in the planning stage of a construction project regarding project milestones and completion times. A realistic schedule allows managers to assess different alternatives rather than placing unrealistic expectations on a construction plan that is very likely to fail. Additionally, realizing in the planning stages that overtime and extra resources will be required to complete a project by a specific date allows management to include for the extra costs in their bid.

Activities that make up a construction project are subject to many factors that cause variation in their duration such as adverse weather, subsurface conditions, change orders, and many others. This results in uncertain project milestone and completion times. The problem is then to analyze the project schedule in an uncertain environment. This research work has specifically addressed this issue.

In this work we have used computer simulation to analyze the project schedule. The first step in the project simulation procedure is to take an existing CPM schedule of the project and convert it into an equivalent simulation representation in SLAMSYSTEM (Pritsker Corporation 1990). This procedure has been automated to assist users unfamiliar with simulation languages and model building concepts. The resulting project simulation model directly incorporates weather into the project simulation study. Weather variables are stochastically generated and the impact on productivity is determined on a daily basis. The schedule is then adjusted to reflect the productivity that occurs for the given day. This process continues for every day until the project is determined to be complete. At this time completion time is determined along with any project milestones. After many simulation runs a range of possible milestone and completion times is obtained. This information is then used by management to determine risk associated with given schedules.

The simulation methodology used in this work is combined discrete-event continuous simulation. This methodology allows direct, daily incorporation of weather effects in the project simulation study. Weather is generated using a stochastic model. This model is conditioned on weather data for the region in which the project will occur. Productivity based on the generated weather conditions is determined using artificial intelligence. Specifically, neural networks have been trained to relate existing productivity values to the the weather conditions under which the given productivity occured. This way we have directly incorporated factors causing productivity variation directly into the schedule.

SIGNIFICANT RESULTS

This work has resulted in several significant contributions to the area of project-level construction simulation. We have built upon popular existing management techniques used in the construction industry. CPM is used extensively in the construction industry for project-level control. Therefore, building the simulation model automatically from CPM schedules is advantageous. Most managers will have a CPM schedule of the construction project so a great deal of extra effort is not required to build a project simulation model. This is done automatically from the existing CPM schedule.

Successful modeling and incorporation of weather processes has shown that it is possible to accurately include these phenomena in project simulation studies. Weather is a difficult factor to model therefore, this should lead to successful incorporation of other uncertainty factors. This level of modeling is advantageous in the sense that is now applicable for any site when given the specific weather parameters and time of year is included automatically in the generation process.

Use of artificial intelligence in productivity forecasting is an entirely new approach in the construction field. From the work done in this research it appears that this approach will be successful for simulation purposes. The nature of the technology makes it simple to include into a project simulation model. Furthermore, the neural network is trained specifically to the data from the company that will be using it. This has the advantage that the productivity model is customized to suit the user.

All aspects of the project simulation model have been developed in Microsoft Windows (Microsoft Corporation 1992) based software. This allows all of the components to be eventually integrated into a single model with relative ease. Integration of the various aspects is beyond the scope of this research effort. However, the model was developed with this in mind.

The use of combined continuous discrete-event simulation has proven to be an effective method of incorporating variables that change on a daily basis into activity durations that are generally days, weeks, or months in length. This approach has not been utilized in construction simulation applications in the past. This research has demonstrated the applicability of this method in construction simulation applications.

LIMITATIONS

This section addresses current limitations of the project simulation methodology presented in this work. It is intended to examine some of the shortcomings of the methodology in its present state but most of all to provide guidance for continuance of the work. Potential solutions are suggested where possible to solve some of the problems put forth in this section. These may assist future researchers in reaching a solution to these problems.

Presently, general purpose simulation languages such as SLAMSYSTEM are affected by personal computer memory limitations that may restrict the total number of activities that can be included in a project simulation model. As new versions of general purpose simulation languages reach the market it is likely that these problems will be alleviated.

One possible solution to this problem is to simulate the project using sub-projects that can operate within the limitations imposed by the simulation environment. The sub-projects can then be combined to form a complete model representing the entire project. Additional programming would be required to solve the problem in this manner.

In this implementation we have not included resource and cost components for the project simulation model. These components are essential to make a proper analysis of any project. There are existing models developed by Pritsker et.al. (1989) that have incorporated these components. Therefore, the next implementation can use the existing models to add this component to the methodology.

Simulation in this work is performed at the project level only. We have not attempted to employ this type of modeling at the process level. Work done by Dabbas and Halpin (1983) appears to be a potential solution. Thus, one could apply the concepts put forth in their work to solve this issue.

Events between the finish of one activity and the beginning of another present another problem. For now, when one activity finishes the next activity begins immediately. It would be beneficial to set up rules that control when the next activity begins. For example, if a preceding activity finishes in mid afternoon it may not be practical to begin the following activity until the next morning. To solve this problem it would be necessary to build some rules that control when the follower activity begins in relation to the completion of the preceding activity.

The final problem associated with the project network deals with task interrelationships. At the present time, only finish-to-start and start-to-start relationships can be modeled. In fact, the automated CPM to SLAMSYSTEM conversion program can only handle finish-to-start relationships. Other relationships present some difficulties to model properly. Furthermore, multiple relationships between tasks are not supported at this time.

Foreseeable limitations of the weather generation component of the model are evident in modeling other factors. Some of the factors not considered here are somewhat difficult to model on a daily basis. For example, wind speed changes often throughout the day and for this reason modeling it on a daily basis may not provide acceptable results. Wind speed is influenced by many factors not included in the model and therefore may be difficult to quantify.

Limitations of the productivity component of the model are not known with complete certainty at this stage of the research. The model must be tested extensively against actual data and predictions made by other models to validate this neural network approach. We feel the concept has great potential, however, rigorous testing is required to validate the model output.

Problems may arise with the productivity component when considering seasonal activities such as earthwork. Most of the data collected will likely be during the season in which the activity is normally scheduled to occur. When the neural network is presented with input values outside of the range that it expects; erroneous results may occur. For example, if weather for January is input (i.e. well outside the normal operating range for earthwork activities in Alberta) unexpected output may be obtained. In addition, the technique for executing certain activities may change from season to season. Placing concrete in winter is normally done with hoarding in place while in summer hoarding is not required. Therefore, placing concrete is a different process in the winter than in the summer. The neural network used in this work does not consider the use of hoarding. When heating is provided in the winter season to the enclosed space around the concrete; outside air temperature has little effect on productivity. Outside air temperature impacts heat requirements but has little effect on the concrete placing operation. These factors should be included in the neural network input slab or separate neural networks constructed to account for different situations.

Finally, data collection to support the neural network productivity forecasting component may also present some problems. Many measures of productivity are not easily collected on a daily basis. In some instances, productivity for a daily report must be estimated; usually in terms of the actual physical progress achieved during the day (i.e. measure of excavated material in a given shift). It is not practical to measure physical output on a daily basis for many activities. Often, physical progress is only measured on a weekly or monthly cycle. This creates problems when one is predicting productivity on a daily basis.

Some of the problems presented in this section are easily overcome while others may require in-depth analysis to resolve. Certainly, others may exist but these were felt to be the most significant. We hope that identifying potential shortcomings of this methodology will be useful in the continuation of this work.

FUTURE RESEARCH DIRECTIONS

Future research should be directed at resolving the issues put forth in the previous section. These problems are the most obvious shortcomings of the model in its present state. Resolving these issues will provide a more effective project simulation environment.

Incorporation of other uncertainty factors in the project simulation study is an obvious extension to the work that has been done here. The framework provided allows for this extension to the model. The primary requirement is data to support the productivity model. When data is available the neural network productivity forecasting approach can be tested further and the incorporation of the other factors can proceed.

Automation of the entire model building and supporting structure development is another future direction for this work. It would be beneficial to link the neural network technology with a database that maintains the productivity data. This module could then be incorporated into the project simulation model. Weather data analysis and parameter determination can be directly incorporated in the model as well. Figure 5-1 illlustrates the conceptual framework for such a system.

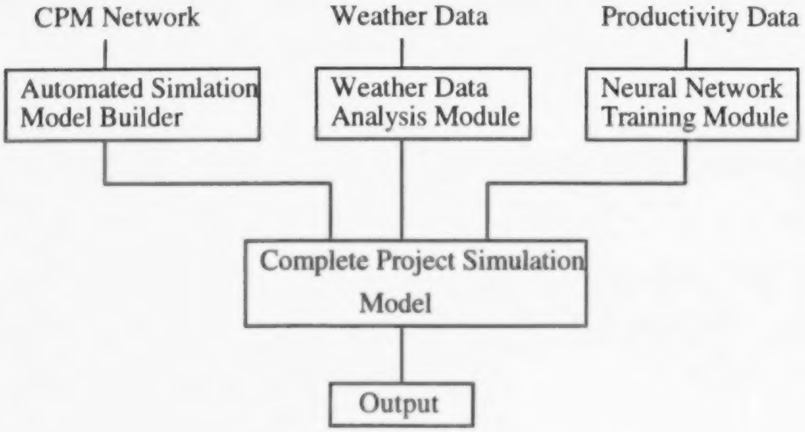
CPM Network
Weather Data
Productivity Data
Automated Simlation Model Builder
Weather Data Analysis Module
Neural Network Training Module
Complete Project Simulation Model
Output

Figure 5-1 Conceptual Framework

Successful incorporation of the components of the present simulation model would provide a powerful project simulation environment. Furthermore, reduced effort would be required by the user when simulating a project schedule.

FINAL REMARKS

This research work has provided a framework for future development in project simulation. Several new methods to the construction simulation field have been adopted to solve some of the problems encountered in the past. The framework provided is flexible to allow modification and improvement to the existing model. Therefore, this research is an effective contribution to the existing practices and allows for future development.

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APPENDIX A: SIMULATION MODEL DEVELOPMENT

A project simulation network is developed by a computer program that uses CPM data as input and converts this information into the equivalent simulation network. At this time the program does not generate all of the necessary files required for simulation. The focus of this work was only to develop the network portion of the simulation model from CPM data. Construction of the remaining files will be the focus of future development of this program.

The project simulation model requires several SLAMSYSTEM (Pritsker Corporation 1990) files plus some user written inserts to become fully functional. The necessary SLAMSYSTEM files are "*.NET", and "*.CON" where the * represents the name of the project. "*.NET" stores the information about the project network, the calendar network, and the "detect nodes" used to track activity progress. "*.CON" stores the control statements that define the operating characteristics of the simulation program. User written files required for this work are the subroutines: "STATE.FOR", "EVENT.FOR", "PRODUCT.FOR", "MATADD.FOR", "MATMULT.FOR", and "BXNRM2.FOR". The "state" subroutine operates in conjunction with the "detect nodes" calculating and tracking activity progress. The "event" routine handles weather generation and determination of productivity factors. Subroutine "product" stores the neural network files and passes productivity factors to subroutine "EVENT". Subroutines "matadd" and "matmult" add and multiply matrices for the weather generation scheme. The subroutine "bxnrm2" generates random numbers sampled from a normal distribution for the weather generation scheme. This automated system provides: "*.NET", "*.CON", and "STATE.FOR". The remaining files are not generated by the automated system at this time. These files are included at the end of this Appendix to illustrate the entire model.

Network development requires information about the construction project activities. Figure A-1 shows a CPM network of an example project. Essentially, the program must be supplied with activity durations, weather sensitivity, and the logical relationships between tasks. This program obtains this information from an ASCII text file of the form shown in Table A-1. The input file must contain an activity description, a unique identifying number, the duration, weather sensitivity (0--non-weather sensitive, >=1--weather sensitivity class), and a list of follower activities. The data is then manipulated to form the network file used in SLAMSYSTEM.

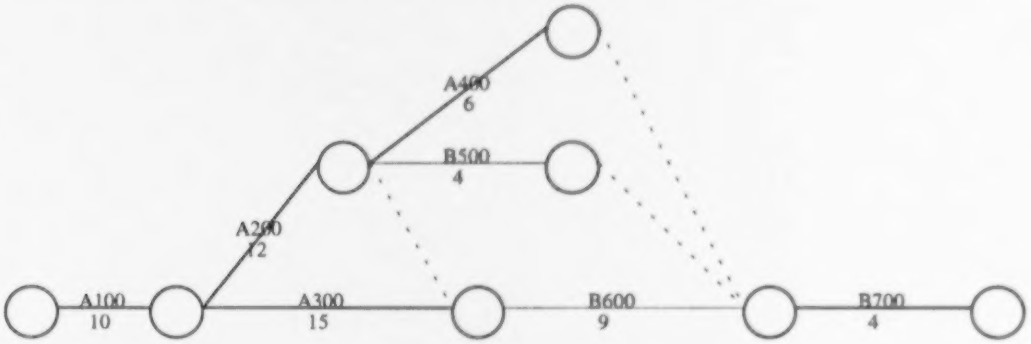


Figure A-1 CPM Diagram

Description	#	Dur.	Weather Sensitivity	Follower Number 1	Follower Number 2	Follower Number 3
Activity 1,	A100,	10,	1,	A200,	A300	
Activity 2,	A200,	12,	1,	A400,	B500	B600
Activity 3,	A300,	15,	2,	B600		
Activity 4,	A400,	6,	0,	B700		
Activity 5,	B500,	4,	1,	B700		
Activity 6,	B600,	9,	3,	B700		
Activity 7	B700	4,	4,			
END						

Table A-1 Project Data File Structure

The data file is read by a subroutine entitled "READACT", the network file is created by the subroutine "CREATENET", the control file is created by "CREATECNT", and the "state" file is created by the subroutine "CREATESTATE". These files are included at the end of this Appendix. After the program has been run the simulation files are obtained from the data file presented in Table A-1. These files are also included at the end of this Appendix.

SAMPLE SESSION

The network developer program is incomplete at this time. However, it does perform the necessary functions to obtain a simulation network of a project from CPM data. The data file used in this work is representative of the data that can be obtained from a CPM network. Further development will allow the program to directly read scheduling software data files from programs such as Microsoft Project (Microsoft Corporation 1992), Primavera Project Planner (Primavera Systems Inc. 1991), and many others. The intent here is to show the algorithm for simulation network development given CPM data.

1. The first step is to create a project data file like that shown in Table A-1. The user creates this file on any text editor and stores it with a ".dat" extension. Now the user may begin the program.
2. The user is presented with a screen having the menu structure shown in Figure A-2. The "File" menu allow the user to create a new project file, open an existing project file, and exit the program. The "Data" menu allows the user to enter the location of the activity data file specified in Step 1. The weather input option is not available at this time. The "Generate" menu creates the network files for the simulation program.

Main Menu

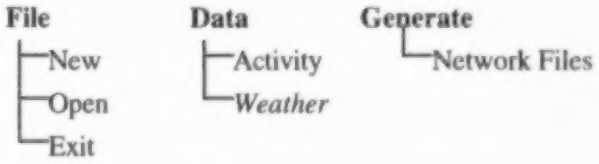
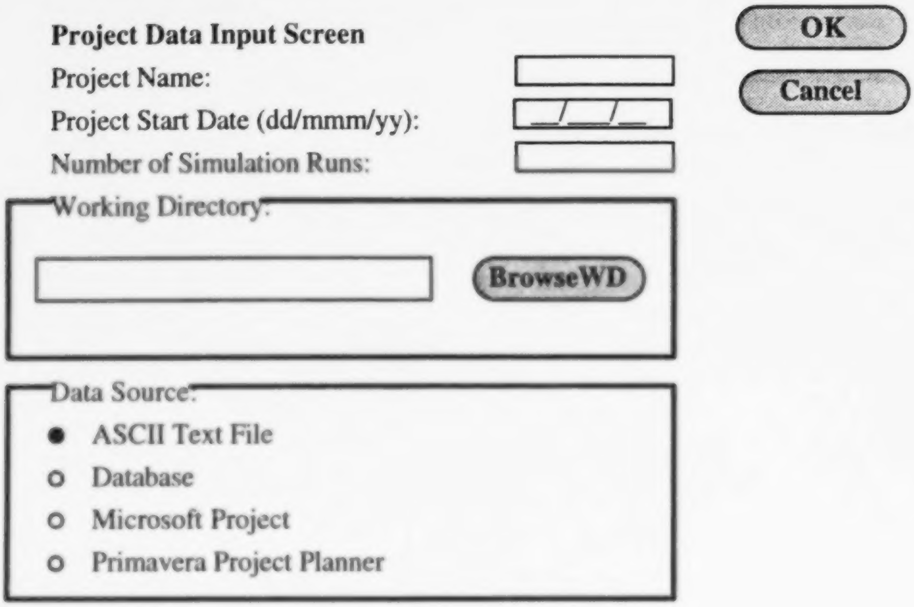


Figure A-2 Menu Structure

3. If a project has already been entered then the user may use the File-Open option. If no project files exist then the user must enter a new project. Figure A-3 displays the new project input screen that appears when the new option is selected. The user must enter a project name (must be a valid DOS name), a project start date, the number of simulation runs to perform, the working directory (i.e., where the files will


Project Data Input Screen
Project Name:
Project Start Date (dd/mmm/yy):
__/___/__
Number of Simulation Runs:
Working Directory:
BrowseWD
Data Source:
OK
Cancel

● ASCII Text File
○ Database
○ Microsoft Project
○ Primavera Project Planner

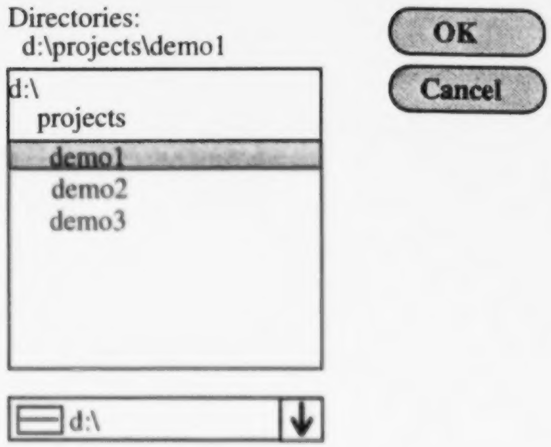
Figure A-3 Project Data Input Screen

be stored), and the data source format. For now the data source format can only be ASCII text file.

When entering the working directory the user may select "BrowseWD" to bring up the screen shown in Figure A-4. The user must only select the proper directory by browsing through the available directories.

In the case where existing projects are already stored the user would select the File-Open command. In this case the screen displayed in Figure A-5 is shown. A list of the available projects is displayed and the user just simply selects the desired project and selects the OK button. At this point the screen shown in Figure A-3 is once again displayed.

4. Once the project data has been entered the location of the activity data file must be given. The user will select the data-activity menu to bring up the screen shown in Figure A-6. When the user selects "BrowseDF" he/she can then browse through the files



Directories: d:\projects\demo1

Figure A-4 Browse Working Directory Screen

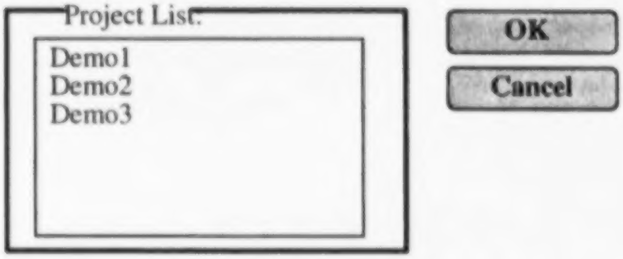
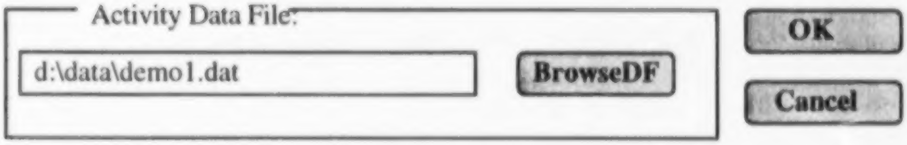


Figure A-5 Open Project Screen



Activity Data File: d:\data\demo1.dat

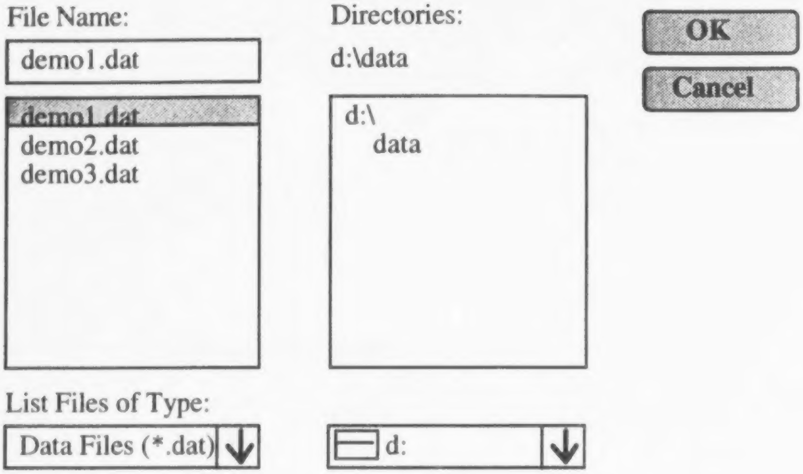
Figure A-6 Activity Data File Screen

using the mouse. The screen shown in Figure A-7 appears when the "BrowseDF" button is pressed.

5. The final step in generating the files is to select the Generate-network files option. This creates the "*.NET", "*.CON", and "STATE.FOR", files.

OUTPUT

The output from the program is listed in the section entitled network developer computer output. Included in the output are the network files, the control file, and



File Name: demo1.dat

demo1.dat
demo2.dat
demo3.dat

Directories: d:\data

d:\
data

List Files of Type: Data Files (*.dat)

d:

Figure A-7 Browse Data File Screen

subroutine "state". The input data file is identical to that shown in Table A-1. Following the computer generated files are the user written subroutines "event", "matadd", "matmult", "product", and "bxnrm2". These files will eventually be incorporated into the automatic generation algorithm.

COMPUTER CODE

The computer code used to generate the files is located in the section entitled network developer computer code.

CONCLUSION

This Appendix presents all of the code necessary for a project simulation to proceed. Many enhancements can still be made to the code to improve the performance. However, the intent is to illustrate the required elements of the proposed project simulation model. Future research can be aimed at improving what has been presented here.

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SLAMSYSTEM. (1990). Pritsker Corporation, Indianapolis, IN.

NETWORK DEVELOPER COMPUTER OUTPUT

```
*****DEMO1.NET FILE*****
;
      CREATE,,,,1,1;
      ACTIVITY,,,AAA1;
AAA1  GOON;
      ACTIVITY/1,REL(END1);
      COLCT,FIRST,END 1;
      ACTIVITY,,,AAA2;
      ACTIVITY,,,AAA3;
AAA2  GOON;
      ACTIVITY/2,REL(END2);
      COLCT,FIRST,END 2;
      ACTIVITY,,,AAA4;
      ACTIVITY,,,AAA5;
      ACTIVITY,,,AAA6;
AAA3  GOON;
      ACTIVITY/3,REL(END3);
      COLCT,FIRST,END 3;
      ACTIVITY,,,AAA6;
AAA4  GOON;
      ACTIVITY/4,6;
      COLCT,FIRST,END 4;
      ACTIVITY,,,AAA7;
AAA5  GOON;
      ACTIVITY/5,REL(END5);
      COLCT,FIRST,END 5;
      ACTIVITY,,,AAA7;
AAA6  ACCUMULATE,2,2,,1;
      ACTIVITY/6,REL(END6);
      COLCT,FIRST,END 6;
      ACTIVITY,,,AAA7;
AAA7  ACCUMULATE,3,3,,1;
      ACTIVITY/7,REL(END7);
      COLCT,FIRST,END 7;
      ACTIVITY,,,PCOMP;
PCOMP GOON;
      COLCT,FIRST,PROJ COMP;
      TERMINATE,1;
;
END1  DETECT,SS(1),XP,10,.5,1;
      ACTIVITY;
      TERMINATE;
;
END2  DETECT,SS(2),XP,12,.5,1;
      ACTIVITY;
      TERMINATE;
;
END3  DETECT,SS(3),XP,15,.5,1;
      ACTIVITY;
      TERMINATE;
;
END5  DETECT,SS(4),XP,4,.5,1;
      ACTIVITY;
      TERMINATE;
;
END6  DETECT,SS(5),XP,9,.5,1;
      ACTIVITY;
      TERMINATE;
;
END7  DETECT,SS(6),XP,4,.5,1;
      ACTIVITY;
      TERMINATE;
;
SCAL  CREATE,,,,1,1;
      ACTIVITY;
      ASSIGN,II=1,1;
      ACTIVITY;
      EVENT,1,1;
      ACTIVITY;
ZAAB  EVENT,2,1;
      ACTIVITY, 1, , ZAAB;
      END;
```

```
*****DEMO.CON FILE*****

GEN,,,03/26/1994,30,Y,Y,Y/Y,Y,Y/S,132;
LIMITS,,6,100;
SEEDS,25697(1),14957(2);
CONTINUOUS,,6,.1,1,1;
INITIALIZE,,1000,N;
NETWORK;
FIN;
```

```
*****STATE.FOR FILE*****

      SUBROUTINE STATE
      COMMON /SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTO
P,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,X
X(100)

      IF(NNACT(2).EQ.1) SS(1)=SSL(1)+DTNOW*ATRIB(7)
      IF(NNACT(3).EQ.1) SS(2)=SSL(2)+DTNOW*ATRIB(4)
      IF(NNACT(4).EQ.1) SS(3)=SSL(3)+DTNOW*ATRIB(4)
      IF(NNACT(5).EQ.1) SS(4)=SSL(4)+DTNOW*ATRIB(4)
      IF(NNACT(9).EQ.1) SS(5)=SSL(5)+DTNOW*ATRIB(6)
      IF(NNACT(10).EQ.1) SS(6)=SSL(6)+DTNOW*ATRIB(3)
      IF(NNACT(11).EQ.1) SS(7)=SSL(7)+DTNOW*ATRIB(3)
      IF(NNACT(13).EQ.1) SS(8)=SSL(8)+DTNOW*ATRIB(3)
      IF(NNACT(15).EQ.1) SS(9)=SSL(9)+DTNOW*ATRIB(3)
      IF(NNACT(17).EQ.1) SS(10)=SSL(10)+DTNOW*ATRIB(3)
      IF(NNACT(19).EQ.1) SS(11)=SSL(11)+DTNOW*ATRIB(3)
      IF(NNACT(21).EQ.1) SS(12)=SSL(12)+DTNOW*ATRIB(3)
      IF(NNACT(23).EQ.1) SS(13)=SSL(13)+DTNOW*ATRIB(6)
      IF(NNACT(24).EQ.1) SS(14)=SSL(14)+DTNOW*ATRIB(3)
      IF(NNACT(25).EQ.1) SS(15)=SSL(15)+DTNOW*ATRIB(3)
      IF(NNACT(26).EQ.1) SS(16)=SSL(16)+DTNOW*ATRIB(6)
      IF(NNACT(27).EQ.1) SS(17)=SSL(17)+DTNOW*ATRIB(3)
      IF(NNACT(29).EQ.1) SS(18)=SSL(18)+DTNOW*ATRIB(4)
      IF(NNACT(30).EQ.1) SS(19)=SSL(19)+DTNOW*ATRIB(5)
      IF(NNACT(31).EQ.1) SS(20)=SSL(20)+DTNOW*ATRIB(6)
      IF(NNACT(32).EQ.1) SS(21)=SSL(21)+DTNOW*ATRIB(5)
      IF(NNACT(33).EQ.1) SS(22)=SSL(22)+DTNOW*ATRIB(5)
      IF(NNACT(34).EQ.1) SS(23)=SSL(23)+DTNOW*ATRIB(5)
      IF(NNACT(37).EQ.1) SS(24)=SSL(24)+DTNOW*ATRIB(7)
      RETURN
      END
```

```
*****EVENT.FOR FILE*****

      SUBROUTINE EVENT(I)
      COMMON /SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTO
P,NCLNR
    1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,X
X(100)

      REAL MXMND(365),MXSDD(365),MXMNW(365),MXSDW(365),RNDNUM
     C,MNMND(365),MNSDD(365),MNMNW(365),MNSDW(365)
     C,PW(12),PWW(12),PWD(12),E(2),A(2,2),B(2,2),T1(2),T2(2)
     C,X0(2),X1(2),BET(12),ALPH(12),MXSD,MXMN,MNSD,MNMN,PRECIP
     C,MAXTEMP,MINTEMP,BXNRM2,RAND1,RAND2,SUM7,SUM(7),AVETEMP

      INTEGER DAY,J,MSTRT(12),MEND(12)

      CHARACTER STATUS*1

*     *****LOAD INITIAL DATA*****
*     MSTRT = Day that each month of the year begins on
*     MEND = Day that each month of the year ends on
*     A = A Matrix values for Weakly Stationary Generating Process
 (WSGP)
*     B = B   "      "      "    "         "         "        "
  "

      DATA MSTRT /1, 32, 60, 91, 121, 152, 182, 213, 244, 274,
     C305, 335/
      DATA MEND /31, 59, 90, 120, 151, 181, 212, 243, 273, 304,
     C334, 365/
      DATA A /-0.521001, -0.732002, 1.192842, 1.404841/
      DATA B /0.708263, 0.634603, 0, 0.258470/

*     *****MAIN PROGRAM*****

      GOTO(1,2),I

*     ********************Event Call 1********************
*     This section loads all of the smoothed seasonal means and
*     standard deviation curves determined from analysis of
*     historical weather data

    1 OPEN (UNIT=9,FILE='MXMND.TXT',STATUS='OLD')
      OPEN (UNIT=10,FILE='MXSDD.TXT',STATUS='OLD')
      OPEN (UNIT=11,FILE='MXMNW.TXT',STATUS='OLD')
      OPEN (UNIT=12,FILE='MXSDW.TXT',STATUS='OLD')
*     MXMND = Mean max daily temp's for dry days
*     MXSDD = Max temp daily standard deviation on dry days
*     MXMNW = Mean max daily temp's for wet days
*     MXSDW = Max temp daily standard deviation on wet days
      READ (9,*) MXMND
      READ (10,*) MXSDD
      READ (11,*) MXMNW
      READ (12,*) MXSDW
      CLOSE(UNIT=9)
      CLOSE(UNIT=10)
      CLOSE(UNIT=11)
      CLOSE(UNIT=12)
      OPEN (UNIT=9,FILE='MNMND.TXT',STATUS='OLD')
      OPEN (UNIT=10,FILE='MNSDD.TXT',STATUS='OLD')
      OPEN (UNIT=11,FILE='MNMNW.TXT',STATUS='OLD')
      OPEN (UNIT=12,FILE='MNSDW.TXT',STATUS='OLD')
*     MNMND = Mean min daily temp's for dry days
*     MNSDD = Min temp daily standard deviation on dry days
*     MNMNW = Mean min daily temp's for wet days
*     MNSDW = Min temp daily standard deviation on wet days
      READ (9,*) MNMND
      READ (10,*) MNSDD
      READ (11,*) MNMNW
      READ (12,*) MNSDW
      CLOSE(UNIT=9)
      CLOSE(UNIT=10)
      CLOSE(UNIT=11)
      CLOSE(UNIT=12)
      OPEN (UNIT=9,FILE='PW.TXT',STATUS='OLD')
      OPEN (UNIT=10,FILE='PWD.TXT',STATUS='OLD')
      OPEN (UNIT=11,FILE='PWW.TXT',STATUS='OLD')
*     PW = Overall probability of a wet day in given month
*     PWD = Probability of a wet day today given a dry day yesterd
ay
*     PWW = Probability of a wet day today given a wet day yesterd
ay
      READ (9,*) PW
      READ (10,*) PWD
      READ (11,*) PWW
      CLOSE(UNIT=9)
      CLOSE(UNIT=10)
      CLOSE(UNIT=11)
      OPEN (UNIT=9,FILE='ALPHA.TXT',STATUS='OLD')
      OPEN (UNIT=10,FILE='BETA.TXT',STATUS='OLD')
*     ALPH = Alpha parameter for two-parameter gamma distribution
*            describing rainfall am'ts for each month
*     BET = Beta parameter for two-parameter gamma distribution
*           describing rainfall am'ts for each month
      READ (9,*) ALPH
      READ (10,*) BET
      CLOSE(UNIT=9)
      CLOSE(UNIT=10)

*     Determine initial day number
*     i.e. 1-for January 1st
*          365 for December 31st
      DAY = XX(1)

*     *****Determine initial precipitation status*****

*     Determine Month of Year (i.e. Jan = 1, Dec = 12)
      DO 6 K=1,12
           IF(DAY.GE.MSTRT(J).AND.DAY.LE.MEND(J)) THEN
                II=J
           ENDIF
  6   CONTINUE

*     Sample uniform random # on [0,1]
      RNDNUM=DRAND(1)
*     Determine precip status
*     If random # is <= probability of a wet day then
*     today is wet otherwise it is dry
      IF(RNDNUM.LE.PW(II)) THEN
           STATUS = 'W'
      ELSE
           STATUS = 'D'
      ENDIF

*     *****Determine initial residuals*****
*     Sample 2 uniform random #'s on [0,1]
      RAND1 = DRAND(1)
      RAND2 = DRAND(2)
*     Determine 2 random numbers sampled from a Normal
*     distribution with mean 0 and variance 1 using the
*     Box Normal procedure
      X0(1) = BXNRM2(RAND1,RAND2)
      X0(2) = BXNRM2(RAND2,RAND1)

*     This loop initializes the residual series to avoid transitio
nal
*     startup problems
*     Also determines initial SUM7 value=sum of previous 7 days pr
ecip
*     Indicates moisture present in soil

      DO 5 J = 1,7
*        Sample uniform random # on [0,1]
         RNDNUM = DRAND(1)
*        Determine precip status (i.e. Wet day or Dry day)
         IF(STATUS.EQ.'D') THEN
         IF(RNDNUM.LE.PWD(II)) THEN
               STATUS = 'W'
               PRECIP = GAMA(BET(II),ALPH(II),1)
               IF(PRECIP.LT.0.2) PRECIP=0.2
            ELSE
               STATUS = 'D'
               PRECIP=0
            ENDIF
         ELSE
            IF(RNDNUM.LE.PWW(II)) THEN
               STATUS = 'W'
               PRECIP = GAMA(BET(II),ALPH(II),1)
               IF(PRECIP.LT.0.2) PRECIP=0.2
            ELSE
               STATUS = 'D'
               PRECIP = 0
            ENDIF
         ENDIF
*        Accumulate SUM7 Value
         SUM(7-J+1) = PRECIP
         SUM7 = SUM7 + PRECIP

*        Sample two uniform random #'s on [0,1]
         RAND1 = DRAND(1)
         RAND2 = DRAND(2)

*        Detemine E matrix values for WSGP
         E(1) = BXNRM2(RAND1,RAND2)
         E(2) = BXNRM2(RAND2,RAND1)
*        Execute WSGP Process
         CALL MATMULT(B,E,T1)
         CALL MATMULT(A,X0,T2)
         CALL MATADD(T1,T2,X1)
*        Determine residuals
         X0(1) = X1(1)
         X0(2) = X1(2)
 5    CONTINUE
```

```
      RETURN

*     *******************Event call number 2********************
*     This section determines all weather variables for each day
*     during simulation
*     Productivity is also determined in this Event Call

*     Determine month of year
    2 DO 10 J = 1,12
           IF(DAY.GE.MSTRT(J).AND.DAY.LE.MEND(J)) THEN
                II=J
                GO TO 20
           ELSEIF(DAY.GT.365) THEN
                II=1
                DAY=1
           ENDIF
  10  CONTINUE

*     *****Determine today's rainfall status*****
*     Sample uniform random # on [0,1]
  20  RNDNUM = DRAND(1)
*     Today's Status determined based on yesterday's status
*     Markov Process
      IF(STATUS.EQ.'D') THEN
           IF(RNDNUM.LE.PWD(II)) THEN
                STATUS = 'W'
           ELSE
                STATUS = 'D'
           ENDIF
      ELSE
           IF(RNDNUM.LE.PWW(II)) THEN
                STATUS = 'W'
           ELSE
                STATUS = 'D'
           ENDIF
      ENDIF

*     *****Determine Residuals for today*****
*     Sample 2 uniform random #'s on [0,1]
      RAND1 = DRAND(1)
      RAND2 = DRAND(2)
*     Determine two random numbers from a normal
*     distribution with a mean of 0 and variance of 1
*     using the Box Normal Procedure
      E(1) = BXNRM2(RAND1,RAND2)
      E(2) = BXNRM2(RAND2,RAND1)

*     *****Calculate new residuals using the WSGP*****
      CALL MATMULT(B,E,T1)
      CALL MATMULT(A,X0,T2)
      CALL MATADD(T1,T2,X1)

*     *****Calculate actual values from residuals*****
      IF(STATUS.EQ.'D') THEN
           MXMN = MXMND(DAY)
           MXSD = MXSDD(DAY)
           MNMN = MNMND(DAY)
           MNSD = MNSDD(DAY)
           PRECIP = 0
      ELSE
```

```
           MXMN = MXMNW(DAY)
           MXSD = MXSDW(DAY)
           MNMN = MNMNW(DAY)
           MNSD = MNSDW(DAY)
           PRECIP = GAMA(BET(II),ALPH(II),1)
           IF(PRECIP.LT.0.2) THEN PRECIP=0.2
      ENDIF

*     Temperature
      MAXTEMP = X1(1)*MXSD+MXMN
      MINTEMP = X1(2)*MNSD+MNMN
      AVETEMP = (MAXTEMP+MINTEMP)/2

*     Put todays residuals into yesterdays residuals
      X0(1) = X1(1)
      X0(2) = X1(2)

*     Determine Productivity Factors
      CALL PRODUCT(MAXTEMP,MINTEMP,PRECIP,SUM7,SUM,
     +ATRIB(3),ATRIB(4),ATRIB(5),ATRIB(6),ATRIB(7))

*     Advance day count
      DAY = DAY + 1

      RETURN
      END
```

*****MATADD.FOR FILE*****

```
      SUBROUTINE MatAdd(Mat1, Mat2, Mat3)

      INTEGER R
      REAL MAT1(2), MAT2(2), MAT3(2)

      DO 10 R = 1, 2
           MAT3(R) = MAT1(R) + MAT2(R)
   10 CONTINUE
      RETURN
      END
```

```
*****MATMULT.FOR FILE*****

      SUBROUTINE MATMULT(MAT1,MAT2,MAT3)

      INTEGER R,COUNT
      REAL MAT1(2,2), MAT2(2), MAT3(2)
      REAL SUM
      DO 10 R = 1,2
           SUM = 0
           DO 20 COUNT = 1, 2
                SUM = SUM + MAT1(R, COUNT) * MAT2(COUNT)
   20      CONTINUE
           MAT3(R) = SUM
   10 CONTINUE
      RETURN
      END
```

```
*****PRODUCT.FOR FILE*****

      SUBROUTINE PRODUCT(MX,MN,PRECIP,SUM7,SUM,PROD1,
     +PROD2,PROD3,PROD4,PROD5)

*     *****This routine determines daily productivity factors usin
g
*     *****Neural network algorithms
*     For now the algorithms are coded directly into this routine
*     In future implementations the neural network will be called
*     directly from the program

      REAL MX, MN, PRECIP, AVETEMP, IN1, N1L0(3,5), N1L1(6)
     +,N1(2,5), SUM7, SUM(7),PROD1,PROD2,PROD3,PROD4,PROD5
     +,N2(2,8),N2L0(4,8),N2L1(9),IN2.IN3,PROD2A,PROD2B
     +,PROD2C

*     Load neural network connection weights for network 1 link 0
      DATA N1L0 / 2.712762,-5.684579,-1.5321,-1.770014,-2.552859
     +,-2.196261,-1.801624,-1.043999,-1.312488,.471348,-2.586959
     +,-2.486684,9.094969,-4.055915,-6.873119 /

*     Load neural network connection weights for network 1 link 1
      DATA N1L1 / -.03915614,-4.607121,-.7556133,.6793392
     +,-1.686149,2.6535 /

*     Load neural network connection weights for network 2 link 0
      DATA N2L0 / -1.877268,.1148172,-2.157829,-3.368239,-2.375862
     +,-.08992995,-.7424613,-1.684406,-2.147091,.1335859,-1.540845
     +,-2.698806,-.8990693,.09830551,-3.397919,-4.575078,1.150117
     +,-4.144117,5.298482,-5.806885,-2.31694,.03046389,-.9547141
     +,-1.994546,-2.093017,.1340426,-1.651778,-2.832446,17.19567
     +,-8.527985,-11.6307,-11.33187 /

*     Load neural network connection weights for network 2 link 1
      DATA N2L1 / -2.283233,1.758827,.7458268,1.444595,1.461499
     +,-1.556602,.9851403,1.511573,2.976754 /

****MAINTAIN LAST SEVEN DAYS PRECIPITATION****
*     SUM7 Parameter
      DO 10 I=7,2,-1
         SUM(I)=SUM(I-1)
  10  CONTINUE
      SUM(1) = PRECIP
      SUM7 = 0
      DO 20 I=1,7
         SUM7=SUM7+SUM(I)
  20  CONTINUE

****CALCULATE AVERAGE TEMPERATURE****
      AVETEMP = (MX+MN)/2

*     *********************************
*     CLASS 1 ACTIVITIES(*CONCRETING*)
*     *********************************

****Neural Network Calculations****
*    *Map input values to [0,1]
*    *Node values for layer 0
      IN1 = (MX+21.06215)/51.1447
      IN2 = (MN+24.70662)/47.52071
```

```
*    *Calculate node values for layer 1
      DO 30 I=1,5
         N1(1,I) = N1L0(1,I)+N1L0(2,I)*IN1+N1L0(3,I)*IN2
         N1(1,I) = 1/(1+EXP(-N1(1,I)))
  30  CONTINUE
*    *Calculate node value for layer 2
      N1(2,1) = N1L1(1)+N1L1(2)*N1(1,1)+N1L1(3)*N1(1,2)+
     +N1L1(4)*N1(1,3)+N1L1(5)*N1(1,4)+N1L1(6)*N1(1,5)
      N1(2,1) = 1/(1+EXP(-N1(2,1)))
*    *Map output from [.1,.9] to real range
      PROD1 = ((N1(2,1)-.1)*1.646063)/.8

      IF(PROD1.LT.0) PROD1 = 0
      IF(MX.GT.40.AND.MN.GT.25) PROD1 = 0

*     ********************************
*     CLASS 2 ACTIVITIES(*EARTHWORK*)
*     ********************************
*     Neural Network Calculations
*    *Map input values to [0,1]
*    *Node values for layer 0
      IN1 = (AVETEMP+11.19567)/38.29538
      IN2 = SUM(1)/20.27774
      IN3 = SUM7/54.71172
*    *Calculate node values for layer 1
      DO 40 I=1,8
         N2(1,I) = N2L0(1,I)+N2L0(2,I)*IN1+N2L0(3,I)*IN2+
     +N2L0(4,I)*IN3
         N2(1,I) = 1/(1+EXP(-N2(1,I)))
  40  CONTINUE
*    *Calculate node value for layer 2
      N2(2,1) = N2L1(1)+N2L1(2)*N2(1,1)+N2L1(3)*N2(1,2)+
     +N2L1(4)*N2(1,3)+N2L1(5)*N2(1,4)+N2L1(6)*N2(1,5)+
     +N2L1(7)*N2(1,6)+N2L1(8)*N2(1,7)+N2L1(9)*N2(1,8)
      N2(2,1) = 1/(1+EXP(-N2(2,1)))
*    *Map output from [.1,.9] to real range
      PROD2 = ((N2(2,1)-.1)/.8)*1.4232
      IF(PROD2.LT.0) PROD2 = 0

*     *********************************************
*     CLASS 3 ACTIVITIES(*WATERPROOFING & PAVING*)
*     *********************************************
      IF(MN.LT.2) THEN
         PROD3 = 0
      ELSEIF(SUM(1).GT.0) THEN
         PROD3 = 0
      ELSE
         PROD3 = PROD1
      ENDIF

*     ***************************
*     CLASS 4 ACTIVITIES(*STEEL*)
*     ***************************
*     For now same as concreting until data available for
*     training from steel erection tasks
      PROD4 = PROD1

*     *****************************
*     CLASS 5 ACTIVITIES(*GENERAL*)
*     *****************************
*     General activities are assumed to be same as concreting
*      for the present time until more data available
       PROD5 = PROD1

       RETURN
       END
```

```
*****BXNRM2.FOR FILE*****

      REAL FUNCTION BXNRM2(RAND1,RAND2)
      REAL PI,RAND1,RAND2,RNORM1,RNORM2
      PI = 3.14159265
*     BOX NORMAL PROCEDURE
*     Determines a random number from a normal distribution
      RNORM1 = SQRT(-2.0 * ALOG(RAND1))
      RNORM2 = 2.0 * PI * RAND2
*     BXNRM1 = RNORM1 * COS(RNORM2)
      BXNRM2 = RNORM1 * SIN(RNORM2)
      RETURN
      END
```

NETWORK DEVELOPER COMPUTER CODE

```
*****READ ACTIVITY DATA SUBROUTINE*****

Sub ReadAct (NumAct As Integer, MaxFol As Integer)

Dim P1 As Integer, P2 As Integer, P3 As Integer, P4 As Integer, P5
 As Integer
Dim r As Integer
ReDim x(1 To 201) As String

'Clear Database
'ActTbl.MoveFirst
If ActTbl.EOF <> -1 Then
    Do
        ActTbl.Delete
        ActTbl.MoveNext
    Loop Until ActTbl.EOF = -1
End If
'FolTbl.MoveFirst
If FolTbl.EOF <> -1 Then
    Do
        FolTbl.Delete
        FolTbl.MoveNext
    Loop Until FolTbl.EOF = -1
End If

Open AsciiFile For Input Access Read As #1

'*****Read all lines from project data file
Do
    i = i + 1
    Line Input #1, x(i)
    If x(i) = UCase$("END") Then Exit Do
Loop

NumAct = i - 1

For j = 1 To NumAct

    ActTbl.AddNew

    ActTbl("ID") = j

    Flag% = 0                                'set exit flag to 0
    P1 = InStr(1, x(j), ",")            'locate the first comma
    ActTbl("Description") = Trim$(Left$(x(j), P1 - 1))          're
ad activity description

    P2 = InStr(P1 + 1, x(j), ",")                'locate second com
ma
    ActTbl("Number") = Trim$(Mid$(x(j), P1 + 1, P2 - P1 - 1))
  'read activity ID

    P3 = InStr(P2 + 1, x(j), ",")                'locate 3rd comma
    ActTbl("Duration") = Val(Mid$(x(j), P2 + 1, P3 - P2 - 1))    'r
ead activity duration

     '*****Weather Sensitivity Data*****

    P4 = InStr(P3 + 1, x(j), ",")                 'locate 4th comma
    If P4 = 0 Then                                  'if no more co
mma's -- last entry for line
```

```
        length% = 10
        Flag% = 1      'set exit flag to 1
    Else
        length% = P4 - P3 - 1
    End If

    ActTbl("WSens") = Val(Trim$(Mid$(x(j), P3 + 1, length%)))

    r = 0

    If Flag% = 1 Then
        GoTo nextline 'last entry has been found for this line got
o next line
    End If

    P5 = InStr(P4 + 1, x(j), ",") 'find first P5% position
    Flag% = 0

    Do
        r = r + 1
        If P5 = 0 Then
            length% = 10
            Flag% = 1
        Else
            length% = P5 - P4 - 1
        End If
        FolTbl.AddNew
        FolTbl("ID") = j
        FolTbl("FolNum") = Trim$(Mid$(x(j), P4 + 1, length%))    'r
ead activity follower
        FolTbl.Update
    If Flag% = 1 Then Exit Do
        P4 = P5
        P5 = InStr(P4 + 1, x(j), ",")
    Loop

    If r > Max Then Max = r

nextline:

ActTbl("NumFol") = r
ActTbl.Update

Next j

Close #1

End Sub
```

```
*****CREATE PROJECT NETWORK SUBROUTINE*****

Sub CreateNet (NumAct, Max, WS%)

x1% = 50
ReDim NP(x1%), NF(x1%), Accum$(x1%), Colct$(x1%), StAct$(x1%), Act
$(x1%)

If Right$(WorkDir, 1) = "\" Then
    NetName$ = WorkDir & UCase$(PName) & ".NET"
Else
    NetName$ = WorkDir & "\" & UCase$(PName) & ".NET"
End If

Open NetName$ For Output Access Write As #1

'*****Determine Activity Characteristics
'*****Number of Predecessors (NP)
'*****Number of Followers (NF)

FolTbl.MoveFirst
FolTbl.Index = "FolNum"
Do Until FolTbl.EOF = -1
    Search$ = FolTbl("FolNum")
    ActTbl.Index = "Number"
    ActTbl.Seek "=", Search$
    ID% = ActTbl("ID")
    Do
        NP(ID%) = NP(ID%) + 1
        FolTbl.Edit
        FolTbl("FolID") = ID%
        FolTbl.Update
        FolTbl.MoveNext
        If FolTbl.EOF = -1 Then Exit Do
    Loop Until FolTbl("FolNum") <> Search$
Loop

ActTbl.Index = "PrimaryKey"
ActTbl.MoveFirst
Do
    Code% = 65
    If ActTbl("ID") < 10 Then
        IDStr$ = Chr$(Code%) & Chr$(Code%) & Chr$(Code%)
        IDStr2$ = "END"
    ElseIf ActTbl("ID") < 100 And ActTbl("ID") >= 10 Then
        IDStr$ = Chr$(Code%) & Chr$(Code%)
        IDStr2$ = "EN"
    End If

    If NP(ActTbl("ID")) = 0 Then
        StrCnt% = StrCnt% + 1
        StAct$(StrCnt%) = "      ACTIVITY,,," & IDStr$ & LTrim$(St
r$(ActTbl("ID"))) & ";"
    End If

    If ActTbl("WSens") = 0 Then
        Act$(ActTbl("ID")) = "      ACTIVITY/" & Trim$(Str$(ActTbl
("ID"))) & "," & Trim$(Str$(ActTbl("Duration"))) & ";"
    ElseIf ActTbl("WSens") >= 1 Then
        WS% = WS% + 1
        Act$(ActTbl("ID")) = "      ACTIVITY/" & Trim$(Str$(ActTbl
("ID"))) & ",REL(" & IDStr2$ & Trim$(Str$(ActTbl("ID"))) & ");"
    End If

    Colct$(ActTbl("ID")) = "      COLCT,FIRST,END " & Trim$(Str$(A
ctTbl("ID"))) & ";"

    If NP(ActTbl("ID")) > 1 Then
        Accum$(ActTbl("ID")) = "ACCUMULATE," & Trim$(Str$(NP(ActTb
l("ID")))) & "," & Trim$(Str$(NP(ActTbl("ID")))) & ",,1;"
    End If
    ActTbl.MoveNext
Loop Until ActTbl.EOF = -1

Print #1, ";"
Print #1, "      CREATE,,,,1," & Trim$(Str$(StrCnt%)) & ";"

'*****Start activity dummy connectors
For i = 1 To StrCnt%
     Print #1, StAct$(i)
Next i

ActTbl.Index = "PrimaryKey"
ActTbl.MoveFirst
Do
    Code% = 65
    If ActTbl("ID") < 10 Then
        IDStr$ = Chr$(Code%) & Chr$(Code%) & Chr$(Code%)
        IDStr2$ = "END"
    ElseIf ActTbl("ID") < 100 And ActTbl("ID") >= 10 Then
        IDStr$ = Chr$(Code%) & Chr$(Code%)
        IDStr2$ = "EN"
    End If

    If NP(ActTbl("ID")) <= 1 Then
        Print #1, IDStr$ & Trim$(Str$(ActTbl("ID"))); Tab(7); "GOO
N;"
    Else
        Print #1, IDStr$ & Trim$(Str$(ActTbl("ID"))); Tab(7); Accu
m$(ActTbl("ID"))
    End If
    Print #1, Act$(ActTbl("ID"))
    Print #1, Colct$(ActTbl("ID"))
    '*****now print dummy connectors
    If ActTbl("NumFol") <> 0 Then
        FolTbl.Index = "ID"
        FolTbl.MoveFirst
        FolTbl.Seek "=", ActTbl("ID")
        For j = 1 To ActTbl("NumFol")
            If FolTbl("FolID") < 10 Then
                IDStrF$ = Chr$(Code%) & Chr$(Code%) & Chr$(Code%)
            ElseIf FolTbl("FolID") < 100 And FolTbl("FolID") >= 10
 Then
                IDStrF$ = Chr$(Code%) & Chr$(Code%)
            End If
            Print #1, "      ACTIVITY,,," & IDStrF$ & Trim$(Str$(F
olTbl("FolID"))) & ";"
            FolTbl.MoveNext
        Next j
    Else
        Pcomp% = Pcomp% + 1
        Print #1, "      ACTIVITY,,,PCOMP;"
    End If
    ActTbl.MoveNext
Loop Until ActTbl.EOF = -1

If Pcomp% <= 1 Then
    Print #1, "PCOMP GOON;"
Else
    Print #1, "PCOMP ACCUMULATE," & Trim$(Str$(Pcomp%)) & "," & Tr
im$(Str$(Pcomp%)) & ",,1;"
End If
Print #1, "      COLCT,FIRST,PROJ COMP;"
Print #1, "      TERMINATE,1;"

'*****Detect Nodes*****

If WS% >= 1 Then
    Print #1, ";"
    ActTbl.Index = "PrimaryKey"
    ActTbl.MoveFirst
    Do Until ActTbl.EOF = -1
        If ActTbl("ID") < 10 Then
            IDStr2$ = "END"
        ElseIf ActTbl("ID") < 100 And ActTbl("ID") >= 10 Then
            IDStr2$ = "EN"
        End If
        If ActTbl("WSens") >= 1 Then
            Cnt% = Cnt% + 1
            ID1$ = Trim$(Str$(ActTbl("ID")))
            ID2$ = Trim$(Str$(Cnt%))
            Dur$ = Trim$(Str$(ActTbl("Duration")))
            Print #1, IDStr2$ & ID1$; Tab(7); "DETECT,SS(" & ID2$
& "),XP," & Dur$ & ",.5,1;"
            Print #1, Tab(7); "ACTIVITY;"
            Print #1, Tab(7); "TERMINATE;"
            Print #1, ";"
        End If
        ActTbl.MoveNext
    Loop
End If

'Create Calender Network
Print #1, "SCAL  CREATE,,,,1,1;"
Print #1, Tab(7); "ACTIVITY;"
Print #1, Tab(7); "ASSIGN,II=1,1;"
Print #1, Tab(7); "ACTIVITY;"
Print #1, Tab(7); "EVENT,1,1;"
Print #1, Tab(7); "ACTIVITY;"
Print #1, "ZAAB  EVENT,2,1;"
Print #1, Tab(7); "ACTIVITY, 1, , ZAAB;"
Print #1, Tab(7); "END;"
'*****Close Channel 1*****

Close #1

End Sub
```

```
*****CREATE SIMULATION CONTROL FILE SUBROUTINE*****

Sub CreateCnt (SeedValue, WS%)

If Right$(WorkDir, 1) = "\" Then
    CntName$ = WorkDir & UCase$(PName) & ".CON"
Else
    CntName$ = WorkDir & "\" & UCase$(PName) & ".CON"
End If

Open CntName$ For Output Access Write As #1

ActTbl.Index = "SortWS"
ActTbl.MoveLast
MaxWS% = ActTbl("WSens")

CurDate$ = Date$
mm$ = Left$(CurDate$, 2)
dd$ = Mid$(CurDate$, 4, 2)
yy$ = Right$(CurDate$, 2)
Atribs$ = Trim$(Str$(MaxWS% + 2))
Print #1, "GEN,," & UCase$(Proj$) & "," & mm$ & "/" & dd$ & "/19"
& yy$ & "," & Trim$(Str$(NoOfRuns%)) & ",Y,Y,Y/Y,Y,Y/S,132;"
Print #1, "LIMITS,," & Atribs$ & ",100;"
Print #1, "SEEDS," & Trim$(Str$(25697)) & "(1)," & Trim$(Str$(1495
7)) & "(2);"
Print #1, "CONTINUOUS,," & Trim$(Str$(WS%)) & ",.1,1,1;"
Print #1, "INITIALIZE,,1000,N;"
Print #1, "NETWORK;"
Print #1, "FIN;"

Close #1

End Sub
```

```
*****CREATE SIMULATION STATE FORTRAN FILE SUBROUTINE*****

Sub CreateState (WS%)

If Right$(WorkDir, 1) = "\" Then
    StName$ = WorkDir & "STATE.FOR"
Else
    StName$ = WorkDir & "\STATE.FOR"
End If

Open StName$ For Output Access Write As #1

Print #1, Tab(7); "SUBROUTINE STATE"
Print #1, Tab(7); "COMMON /SCOM1/ ATRIB(100),DD(100),DDL(100),DTNO
W,II,MFA,MSTOP,NCLNR"
Print #1, Tab(6); "1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100
),TNEXT,TNOW,XX(100)"

If WS% >= 1 Then
     Print #1,
     ActTbl.Index = "PrimaryKey"
     ActTbl.MoveFirst
     Do Until ActTbl.EOF = -1
          If ActTbl("WSens") >= 1 Then
               Cnt% = Cnt% + 1
               ID1$ = Trim$(Str$(Cnt%))
               ID2$ = Trim$(Str$(ActTbl("ID")))
               ID3$ = Trim$(Str$(ActTbl("WSens") + 2))
               Print #1, Tab(7); "IF(NNACT(" & ID2$ & ").EQ.1) SS(
" & ID1$ & ")=SSL(" & ID1$ & ")+DTNOW*ATRIB(" & ID3$ & ")"
          End If
          ActTbl.MoveNext
     Loop
     Print #1, Tab(7); "RETURN"
     Print #1, Tab(7); "END"
End If

Close #1

End Sub
```

APPENDIX B: WEATHER GENERATION MODEL

Stochastic weather variable generation requires identifying properties of observed weather sequences. This allows the generation of numerous weather sequences for simulation experiments all having the same underlying properties. In this study, precipitation is considered the primary variable and all other variables are conditioned on the precipitation status of the day (Richardson 1981).

PRECIPITATION COMPONENT

Precipitation modeling uses a two-state (wet, dry) first-order Markov chain to determine the occurence of wet or dry days and a two parameter gamma distribution to determine precipitation amount. Precipitation status (wet or dry) of a given day is conditioned on the status of the previous day using the first-order Markov chain. Each day is classified as wet or dry depending on the amount of precipitation that has fallen. A day in which 0.2 millimeters or more precipitation has fallen is classified as a wet day. In the case of snowfall, equivalent water depth is used as a measure of precipitation amount.

The Markov chain process is modeled using the procedure presented by Smith and Hancher (1989). The two-state Markov chain is defined by transitional probabilities of moving from one state to another from one day to the next. Transitional probabilities are dependent on the time of year for most locations (Richardson 1981). Therefore, separate transitional probabilities are calculated for each month of the year to reflect the seasonality of these parameters. Equation (1) defines the transitional probabilities of transiting from state i on day d-1 to state j on day d.

$$P_{m,d}(j / i) = \frac{n_{ij}}{n_i} \qquad (1)$$

The count of transitions from state i to state j is denoted by n_{ij} and n_i is the count of all transitions from state i to the other states for month m and x years of record.

When simulation begins the status of the previous day is not known. Therefore, the overall probability of a day being wet or dry must be determined in order to establish the initial precipitation status. The probability that any given day is in state *i* for month m can be calculated by Equation (2).

$$P_m(i) = \frac{N_i}{X_m} \quad \ldots\ldots \quad (2)$$

The count of all days observed in state *i* is denoted by N_i and X_m is the total number of days in *x* years of record for month *m*.

Clearly, it is only necessary to define 2 transitional probabilities and 1 overall probability to fully define the model. For this model $P_{m,d}$(W/W), $P_{m,d}$(W/D), and P_m(W) are determined where: $P_{m,d}$(W/W) is the probability of a wet day on day *d* given a wet day on day *d-1* in month *m*; $P_{m,d}$(W/D) is the probability of a wet day on day *d* given a dry day on day *d-1* in month *m*; and P_m(W) is the overall probability of a wet day in month *m*.

Generation of wet days requires determination of a precipitation amount. A two-parameter gamma distribution is fit to historical records through the moment matching procedure. Again, a separate gamma distribution is determined for each month of the year to reflect seasonality of precipitation amounts. The two-parameter gamma distribution is described by Equation (3a).

$$f(x) = \frac{1}{\Gamma(\alpha)\beta^{\alpha}} \exp\left[-\frac{x}{\beta}\right] x^{\alpha-12}; x > 0 \quad \ldots\ldots \quad (3a)$$

$$\mu = \alpha\beta \quad \ldots\ldots \quad (3b)$$

$$\sigma^2 = \alpha\beta^2 \quad \ldots\ldots \quad (3c)$$

The mean (μ) and variance (σ^2) are related to the alpha (α) and beta (β) parameters by equations (3b) and (3c). The mean and variance of the historical records is matched to that of the gamma distribution and the resulting alpha and beta parameters are calculated to describe the gamma distribution for each month. Figure B-1 shows the fit obtained for the month of July.

Precipitation parameters are fully defined by calculating Markov chain transitional probabilities and gamma distribution parameters. Table B-1 displays a summary of the

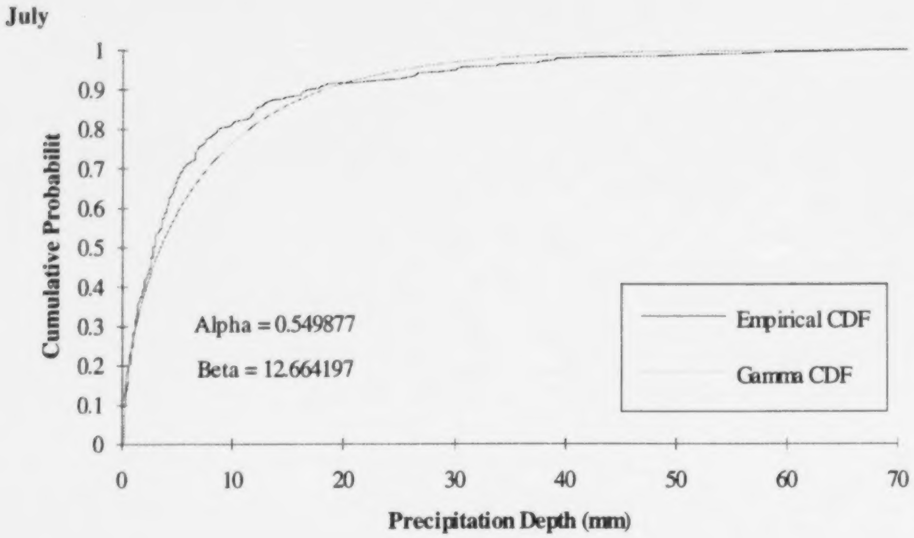

Figure B-1 Cumulative Gamma Density Function

Month	P_m(W/D)	P_m(W/W)	P_m(W)	Alpha (α)	Beta (β)
January	0.433333	0.566667	0.353226	0.775529	2.234496
February	0.462857	0.537143	0.325000	1.214286	1.441091
March	0.596591	0.403409	0.287097	0.683679	2.701456
April	0.608696	0.391304	0.238333	0.710126	4.844945
May	0.493023	0.506977	0.358065	0.718201	6.102239
June	0.413534	0.586466	0.465000	0.662894	9.293379
July	0.479401	0.520599	0.440323	0.549877	12.664197
August	0.516129	0.483871	0.411290	0.681798	8.425219
September	0.477157	0.522843	0.340000	0.923529	5.314970
October	0.625000	0.375000	0.214516	0.794643	3.410225
November	0.534483	0.465517	0.298333	0.793266	1.771274
December	0.470046	0.529954	0.359677	0.728183	2.740692

Table B-1 Precipitation Parameters

precipitation variables for the Edmonton Municipal Airport Weather station based on the years 1972 to 1991. Precipitation data for the 20 years of record is presented in Appendix C. Remaining weather variables are now determined based on the precipitation status of the day.

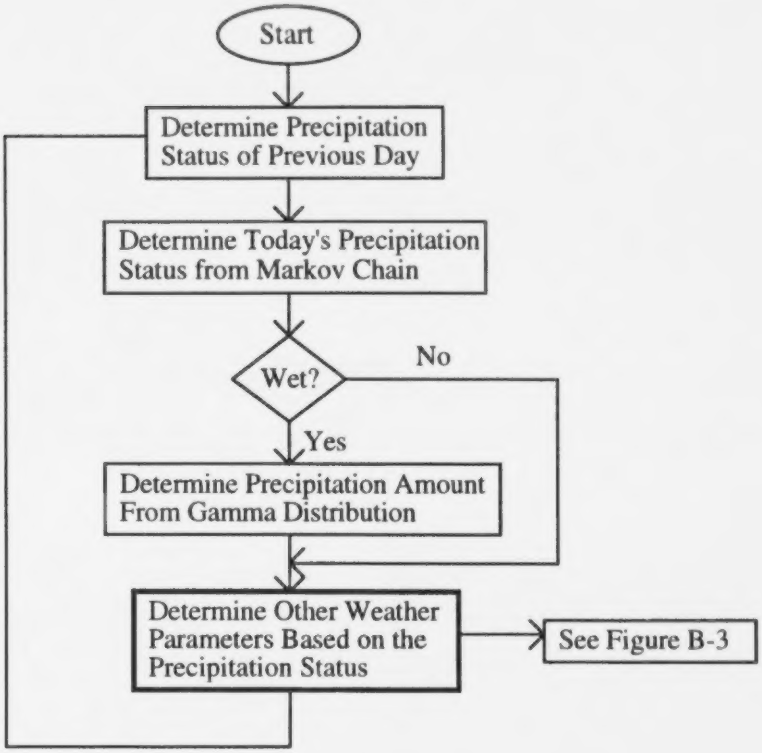
Start
Determine Precipitation Status of Previous Day
Determine Today's Precipitation Status from Markov Chain
Wet?
No
Yes
Determine Precipitation Amount From Gamma Distribution
Determine Other Weather Parameters Based on the Precipitation Status
See Figure B-3

Figure B-2 Precipitation Simulation Procedure

The precipitation component of the project simulation model operates according to the flowchart shown in Figure B-2. After simulation begins the precipitation status of the previous day must be determined in order to use the Markov transitional probabilities to determine the precipitation status for the current day. A random number is sampled from a uniform distribution between 0 and 1. If the random number is less than or equal to the probability of a wet day in the current month, $P_m(W)$, then the previous day is considered wet. Otherwise, the previous day is dry. Today's precipitation status is determined from the Markov transitional probabilities for the current month. Again, a random number is sampled from a uniform distribution between 0 and 1. If the previous day was wet, today is also wet if the random number is less than or equal to $P_m(W/W)$. Otherwise today is dry. If the previous day was dry, today is wet if the random number is less than or equal to $P_m(W/D)$. Otherwise the status of the current day is dry.

When wet days are generated a precipitation amount is determined from a two-parameter gamma distribution for the current month. Two uniform random numbers are generated between 0 and 1. The numbers are mapped onto the gamma function by a procedure that depends on the value of alpha (α) to determine a precipitation amount. For values of alpha greater than 0 and less than 1 the method of Jöhnk is employed (Berman 1970). When alpha is greater than or equal to 1 and less than 5 the method of Fishman (1976) as modified by Tadikamalla ("Computer..." 1978; "Computer...II" 1978) is employed. Although there were no cases of alpha being greater than or equal to 5 a weighted selection of Erlang samples would be employed (Pritsker 1986). Other weather variables are determined at this point according to the procedure described in the following section. Next, time advances one day and the precipitation status is determined from the Markov chain and the procedure repeats.

MAXIMUM AND MINIMUM TEMPERATURE COMPONENT

The approach used in this component of the model considers maximum and minimum temperatures to be a continuous multivariate stochastic process with daily means and standard deviations conditioned on the precipitation status of the day (Richardson 1981). Following the technique of Yevjevich (1972) the historical time series records are first reduced to a series of residuals by removing the periodic mean and standard deviation. Equations (4a) and (4b) are used to determine residual elements of each series.

$$\chi_{y,d}(i) = \frac{X_{y,d}(i) - \overline{X}_d^0(i)}{\sigma_d^0(i)}, P_{y,d} = 0 \quad \text{.......} \quad (4a)$$

$$\chi_{y,d}(i) = \frac{X_{y,d}(i) - \overline{X}_d^1(i)}{\sigma_d^1(i)}, P_{y,d} > 0 \quad \text{.......} \quad (4b)$$

The subscripts y and d refer to the year and day respectively for each variable. The variable $\chi_{y,d}(i)$ is the residual element for variable i; $X_{y,d}(i)$ is the value of variable i; $\overline{X}_d^0(i)$ is the periodic mean of variable i on dry day d; $\sigma_d^0(i)$ is the periodic standard deviation of variable i on dry day d; $\overline{X}_d^1(i)$ is the periodic mean of variable i on wet day d; $\sigma_d^1(i)$ is the periodic standard deviation of variable i on wet day d; and $P_{y,d}$ is the precipitation in millimeters. Periodic means and standard deviations are determined by calculating the mean and standard deviation for each day of the year based on the wet or dry status of the day and smoothing the results with a general regression neural network. This results in a periodic mean curve for wet days, a periodic mean curve for dry days, a periodic standard deviation curve for wet days, and a periodic standard deviation curve for dry days. Periodic means and standard deviations in equations (4a) and (4b) are determined from the smoothed curves.

Residual elements are the basis of the weather generation scheme. This work uses the weakly stationary generating procedure suggested by Matalas (1967) which generates residual elements of the weather variables based on the residuals from the day before plus a random component. Actual values are determined by solving for $X_{y,d}(i)$ in equations (4a) and (4b) depending on the precipitation status. The weakly stationary generating process is defined by equation (5) for n weather variables.

$$\chi_{y,d}(i) = A\chi_{y,d-1}(i) + B\varepsilon_{y,d}(i) \tag{5}$$

The variables $\chi_{y,d}(i)$ and $\chi_{y,d-1}(i)$ are (n x 1) matrices of residual elements for year y and day d and d-1 for variables i to n; $\varepsilon_{y,d}(i)$ is a (n x 1) matrix of independent random components sampled from a normal distribution with a mean of 0 and a variance of 1; and A and B are (n x n) matrices defined such that the time dependence and interdependence structure of the historical residual series is preserved. Use of (5) implies that the residual series of each weather variable is normally distributed and a first-order linear autoregressive model describes the serial correlation of each variable (Matalas 1967). These implications will be addressed in the final section.

A and B matrices ensure the generated residual series maintain the serial and cross-correlation characteristics of the historical series. Matrices A and B may be determined from equations (6) and (7).

$$\mathrm{A} = \mathrm{M}_1 \mathrm{M}_2^{-1} \qquad (6)$$

$$\mathrm{BB}^{\mathrm{T}} = \mathrm{M}_0 - \mathrm{M}_1 \mathrm{M}_0^{-1} \mathrm{M}_1^{\mathrm{T}} \qquad (7)$$

M_0 and M_1 are (n x n) lag 0 and lag 1 covariance matrices of the residual series. Variances of the residual series were approximately equal to 1, therefore M_0 and M_1 are essentially matrices containing lag 0 and lag 1 cross-correlation coefficients. M_0 and M_1 are defined by (8) and (9).

$$M_0 = \begin{bmatrix} 1 & \rho_0(1,2) & \cdots & \rho_0(i,j) \\ \rho_0(2,1) & 1 & & \vdots \\ \vdots & & 1 & \vdots \\ \rho_0(j,i) & \cdots & \cdots & 1 \end{bmatrix} \qquad (8)$$

$$M_1 = \begin{bmatrix} \rho_1(1) & \rho_1(1,2) & \cdots & \rho_1(i,j) \\ \rho_1(2,1) & \rho_1(2) & & \vdots \\ \vdots & & \ddots & \vdots \\ \rho_1(j,i) & \cdots & \cdots & \rho_1(i) \end{bmatrix} \qquad (9)$$

The variable $\rho_0(i,j)$ is the lag 0 cross correlation coefficient between variables i and j; $\rho_1(i)$ is the lag 1 serial correlation coefficient for variable i; $\rho_1(i,j)$ is the cross correlation coefficient between variables i and j with variable j lagged one day with respect to variable i. For this example only maximum and minimum temperature are being generated so M_0 and M_1 are 2 x 2 matrices. For the Edmonton Municipal Airport Weather Station these values were computed for maximum and minimum temperature series for the years 1972 to 1991 and were found to have the values shown below. Maximum and minimum temperature data is presented in Appendix C.

$$M_0 = \begin{bmatrix} 1.000000 & 0.962192 \\ 0.962192 & 1.000000 \end{bmatrix}$$

$$M_1 = \begin{bmatrix} 0.626742 & 0.691539 \\ 0.619725 & 0.700515 \end{bmatrix}$$

Solving for the values of the A matrix is simple and straightforward, however, solving for the B matrix values is more complicated due to the construction of the matrix equation. Following the solution procedure suggested by Young (1968) B is assumed to be a lower triangular matrix. Matrix C is defined by equation (10). In the case of a 2 x 2 matrix equation (10) takes the form of the equation shown in (11). The elements of B can be determined from equations (12), (13), and (14).

$$C = BB^T = M_0 - M_1 M_0^{-1} M_1 \quad \text{.......(10)}$$

$$C = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \quad \text{.......(11)}$$

$$b_{11} = \sqrt{c_{11}} \quad \text{.......(12)}$$

$$b_{21} = \frac{c_{21}}{b_{11}} \quad \text{.......(13)}$$

$$b_{22} = \sqrt{c_{22} - b_{21}^2} \quad \text{.......(14)}$$

For matrices having dimensions greater than 2 x 2 one can simply deduce the proper solutions for the elements of the B matrix using the same procedure. Using the equations above, the elements of A and B for the sample data were determined and are shown below.

$$A = \begin{bmatrix} -0.521001 & 1.192842 \\ -0.732002 & 1.404841 \end{bmatrix}$$

$$B = \begin{bmatrix} 0.708263 & 0 \\ 0.634603 & 0.258470 \end{bmatrix}$$

The elements of equation (5) are now fully defined. Generation of maximum and minimum temperatures follows the process shown in Figure B-3. The temperature routine is called from the precipitation routine of Figure B-2. The first step is to sample two random numbers from a normal distribution with a mean of zero (0) and a variance of one (1). These two numbers form the random component of the weakly stationary generating process. If this is the first run through the simulation procedure (e.g., day 1 of the project) the residual generation procedure is initialized to reduce any transitional startup problems. Therefore, on the first run the previous days residuals are sampled from a normal distribution (mean = 0, variance = 1). A new set of residuals is generated by applying the weakly stationary generating procedure. The new residuals are then placed in variables holding the previous days residuals and the process is repeated. After 5 initializing runs control is passed back to the main routine and the current day's residuals are determined from the weakly stationary generating process. Actual temperature values are determined by solving for $X_{y,d}(i)$ in equation (4a) or (4b) depending on the precipitation status of the day. Control is then returned to the precipitation routine.

TEST OF ASSUMPTIONS

The first implication is that the residual series of each variable is normally distributed. This is tested by calculating the moments of the residual series data and comparing them with the normal distribution. The moments are shown in Table B-2. By virtue of the construction the residual series should exhibit a mean of 0 and a standard deviation of 1 (Richardson, 1981). Use of equations (4a) and (4b) successfully reduced the series to residuals with a mean of 0 and a standard deviation of 1. The skewness was slightly negative indicating that the distribution is slightly skewed to the left but it is very close to 0. Kurtosis of the residual series is very close to 3 in both cases which is indicative of a normally distributed sample. For these reasons, it is apparent that the first implication is satisfied.

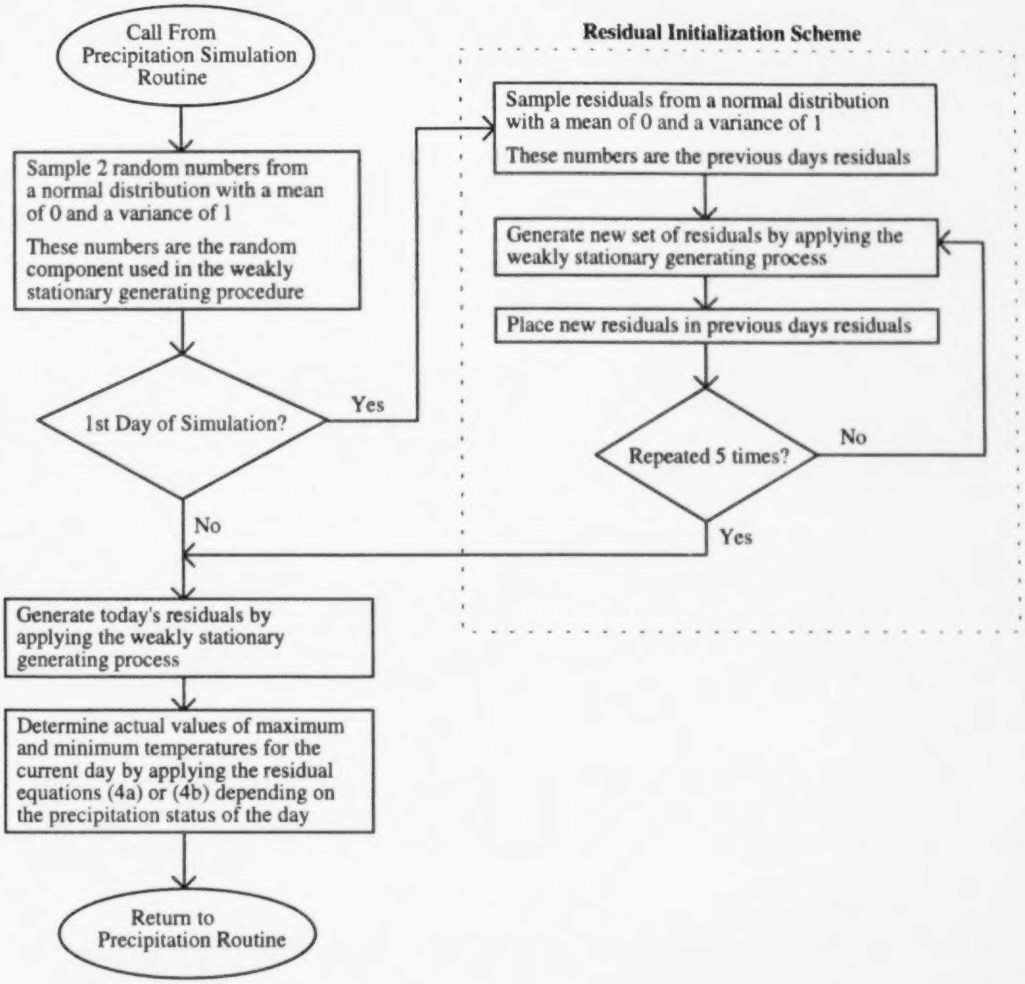
Call From Precipitation Simulation Routine
Sample 2 random numbers from a normal distribution with a mean of 0 and a variance of 1
These numbers are the random component used in the weakly stationary generating procedure
1st Day of Simulation?
Yes
No
Residual Initialization Scheme
Sample residuals from a normal distribution with a mean of 0 and a variance of 1
These numbers are the previous days residuals
Generate new set of residuals by applying the weakly stationary generating process
Place new residuals in previous days residuals
Repeated 5 times?
No
Yes
Generate today's residuals by applying the weakly stationary generating process
Determine actual values of maximum and minimum temperatures for the current day by applying the residual equations (4a) or (4b) depending on the precipitation status of the day
Return to Precipitation Routine

Figure B-3 Temperature Simulation Procedure

Variable	μ	σ	Skewness	Kurtosis
Maximum Temperature Residuals	0.022	1.089	-0.254	3.002
Minimum Temperature Residuals	0.037	1.088	-0.314	3.070

Table B-2 Moments of Sample Data

The second implication states that the serial correlation of the residual series is described by a first-order linear autoregressive model. A first-order autoregressive model defines serial dependence as $\rho_k = \rho_1^k$, where ρ_k is the serial correlation for lag k. Figure B-4 shows the comparison between the first-order model and the serial correlation coefficients.

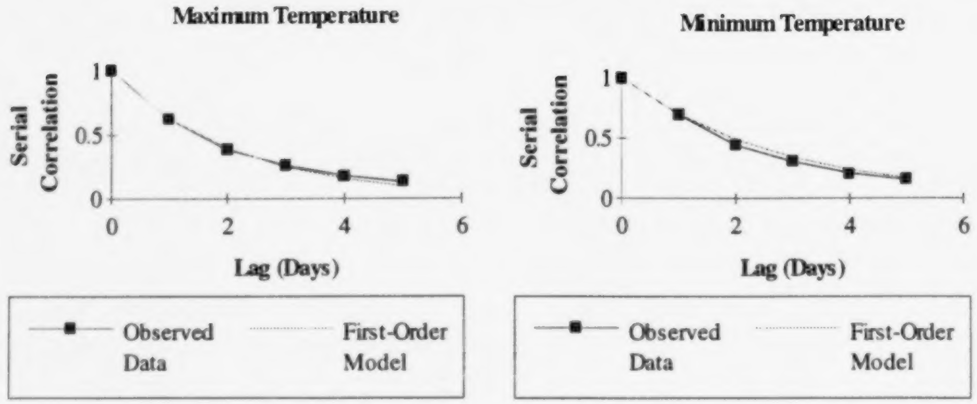

Figure B-4 Autoregressive Model vs Serial Correlation

It is obvious from Figure B-4 that the serial correlation of the residual series closely approximates that of the first-order linear autoregressive model and therefore the second implication is satisfied. Therefore, this is a viable model for generation of weather variables for project simulation studies.

OUTPUT TESTING

The weather generation model used in this research is tested to ensure that the model produces satisfactory results. Testing is performed by generating 10 years of weather data for the Edmonton Municipal Airport Weather station and comparing the simulated means by month to the actual values computed from 20 years of record (1972-91).

Mean monthly minimum temperatures, maximum temperatures, precipitation amounts, and number of wet days were computed from the actual weather station data. Standard deviations of each of the above parameters was also determined to establish confidence intervals around the calculated means. The simulated means are then compared to the values obtained from the actual data. Tables B-3 through B-6 list the actual mean, actual standard deviation, lower and upper limits (1% level) and the mean of the simulated weather data.

Month	Actual μ	σ	Lower Limit	Upper Limit	Generated μ	Within Limits
January	20.1	15.5	11.30	28.90	22.4	✓
February	16.4	8.1	11.80	21.00	17.1	✓
March	18.4	12.0	11.59	25.21	17.6	✓
April	25.2	12.7	17.99	32.41	33.0	✗
May	50.7	29.8	33.78	67.62	54.6	✓
June	88.5	42.9	64.14	112.86	84.1	✓
July	95.5	51.1	66.49	124.51	100.5	✓
August	72.2	39.9	49.55	94.85	84.6	✓
September	45.0	28.0	29.10	60.90	47.2	✓
October	19.8	16.2	10.60	29.00	20.7	✓
November	14.6	11.4	8.13	21.07	13.5	✓
December	23.0	13.1	15.56	30.44	21.4	✓

Table B-3 Comparison of Rainfall Amounts

The month of April was the only month to show a significant difference between the actual and generated means for monthly precipitation. All other means were not significantly different at the 1% level. Table B-4 lists the comparison of means for the number of wet days occurring in each month. April and May generated means were significantly different at the 1% level. Table B-5 compares generated mean monthly minimum temperatures to the actual values. May and June were the only months that had

Month	Actual μ	σ	Lower Limit	Upper Limit	Generated μ	Within Limits
January	10.9	5.1	8.00	13.80	13.2	✓
February	9.1	3.6	7.06	11.14	9.9	✓
March	8.9	3.2	7.08	10.72	10.4	✓
April	7.2	2.8	5.61	8.79	9.8	✗
May	11.1	3.0	9.40	12.80	13.3	✗
June	13.9	3.3	12.03	15.77	14.8	✓
July	13.6	3.2	11.78	15.42	14.7	✓
August	12.8	4.8	10.07	15.53	13.5	✓
September	10.2	3.3	8.33	12.07	10.9	✓
October	6.7	3.2	4.88	8.52	7.8	✓
November	8.9	5.0	6.06	11.74	9.9	✓
December	11.1	4.3	8.66	13.54	12.1	✓

Table B-4 Comparison of Number of Wet Days

generated means significantly different at the 1% level. Table B-6 compares generated mean monthly maximum temperatures to the actual values. Again, May and June had generated means significantly different at the 1% level.

Month	Actual μ	σ	Lower Limit	Upper Limit	Generated μ	Within Limits
January	-10.7	4.7	-13.37	-8.03	-11.8	✓
February	-8.6	5.3	-11.61	-5.59	-7.3	✓
March	-2.7	3.3	-4.57	-0.82	-2.5	✓
April	5.5	2.3	4.19	6.81	5.0	✓
May	11.8	1.3	11.06	12.54	10.8	×
June	15.6	1.0	15.03	16.17	15.0	×
July	17.6	1.0	17.03	18.17	17.1	✓
August	16.5	1.9	15.42	17.58	15.6	✓
September	11.2	2.0	10.06	12.34	11.1	✓
October	5.8	1.8	4.78	6.82	5.1	✓
November	-4.2	4.0	-6.47	-1.93	-4.3	✓
December	-9.4	4.1	-11.73	-7.07	-9.6	✓

Table B-5 Comparison of Minimum Temperatures

Month	Actual μ	σ	Lower Limit	Upper Limit	Generated μ	Within Limits
January	-6.3	4.7	-8.97	-3.63	-7.2	✓
February	-4.0	5.6	-7.18	-0.82	-2.8	✓
March	2.0	3.5	0.01	3.99	2.3	✓
April	11.3	3.0	9.60	13.00	10.4	✓
May	17.7	1.7	16.73	18.67	16.3	×
June	21.3	1.2	20.62	21.98	20.5	×
July	23.1	1.4	22.31	23.89	22.6	✓
August	21.9	2.3	20.59	23.21	21.0	✓
September	16.6	2.6	15.12	18.08	16.4	✓
October	11.0	2.2	9.75	12.25	10.2	✓
November	0.0	4.3	-2.44	2.44	0.1	✓
December	-5.1	4.2	-7.48	-2.72	-5.2	✓

Table B-6 Comparison of Maximum Temperatures

The capability of the model to reproduce the distribution of annual extreme temperatures is tested by calculating the mean annual maximum and minimum temperatures. Furthermore, the mean number of days with a temperature greater than or equal to 25°C and days with a temperature less than or equal to -10°C are calculated. Table B-7 lists the results.

Variable	Actual μ	σ	Lower Limit	Upper Limit	Generated μ	Within Limits
Maximum Temperature (°C)	9.1	1.2	8.4	9.8	9.4	✓
Minimum Temperature (°C)	4.0	1.1	3.4	4.6	4.3	✓
Days >= 25°C	32.5	5.6	29.3	35.7	29.5	✓
Days <=-10°C	50.3	16.2	41.1	59.5	48.3	✓

Table B-7 Extreme Temperature Comparison

In all of the extreme temperature tests the generated mean values were not significantly different at the 1% level. It is apparent that the model is producing satisfactory results for the variables generated in this test. Since very few of the means were significantly different at the 1% level we feel that this weather generating model will operate effectively in the project simulation model.

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APPENDIX C: WEATHER DATA

Weather data used for the weather generation model of this research is included here. This information was obtained from Environment Canada. Table C-1 lists precipitation data, Table C-2 lists maximum temperature data, and Table C-3 contains the minimum temperature data from 1972 to 1991 recorded at the Edmonton Municipal Airport Weather station.

TABLE C-1 PRECIPITATION DATA

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	0	0	0.5	0	1	0	0	0.2	0	0	1	0	0	0	0.5	0	0	0	0	0
2	0	9.1	1	0	0.3	0.3	0	0	0	0	0.6	0	0.2	0	0	0	0	0	0.2	0
3	0	0.8	2.5	0	0	0.3	2	0	6.7	0	1	0.2	0	0	0	0	0	0	2.4	0
4	0.8	0	0.3	0.3	4.3	0	2.2	0	3	0	0.2	0	1.2	0	0	0	0	0	3	0
5	0.8	0.3	0.5	0	2.3	0	5.7	0	10.6	0	0	0	0	0	0	0	0	1.2	0	0
6	0	0.8	1	0	1	0.3	0.7	0	0	6.7	1	0	0	0	0.9	0	0	1.9	0	0
7	0	0	0.8	2.3	0	3.8	0	0	0	0	9.9	0	0	0	0	0	0.4	0	0	0
8	0	0.3	0	2.8	2	0.3	2.6	0	0	0.4	7.6	0	0.2	0.4	0	0	0	0	0	0
9	0	0.3	0	0.5	0	1.8	0.2	0	0	0.8	4	0	0	0.2	0	0	0	0	0	0
10	0	0	0	0	0	0.3	0	0	2.1	0	3.8	0	6.9	0	0	0	1.8	0	1.6	0
11	1.3	0	0	0	0	0	0	0.4	0	0	1	0.6	0.8	0	0	0	0	0	0	0
12	0	0	0	1	0	2.4	0.8	0.2	0	0	0.2	0	0.4	0	0	1.8	0.2	0.4	0	0
13	0	0	6.6	0	0	2	0	0	0	0	5	0	0	0	0	1.8	0	0	0	0
14	1.5	0	7.1	0	0	0.3	0.4	0	0	0	5.2	0	0	2.2	0	0	0	0.2	0	0
15	0.8	0	1	0	0.3	0.5	0.7	0	0	0	0	0	4.4	1.4	0	0	0	0.6	0	0
16	0.5	0	0.3	0	0.3	0	0	0	0	0	0	0	1.1	6.1	0	0	0	0	0.4	0
17	7.1	0	0	0.5	0	0.5	1.1	0	0	0	4.6	0	0.3	2.2	2.4	1.8	0	0	0	0
18	0	0	0	0	0	0.3	0	0	0	0	1.1	0	1.5	2	0	0	0	0	0	0
19	0.8	0	0	3.3	0	0	0	3.6	0	0	0	0	0	0	3.4	0	0	0	0	0
20	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	0	0	0	0	0	0	1.3	0	0	1.5	0.2	0.4	0	0	0	0	0	0	0
22	2	0	2	0	0.3	0	0.2	1	0	0	2.6	1.3	0	0	0	0	2	0	0.8	0.2
23	0	0	1.3	0	1.8	0	0	0.9	1.8	0	1	0.8	1.7	0	1.2	0	0	0	0	0.4
24	0	0	0	0	0.8	0	0	0.4	2.8	0	4.4	0	2.6	0	0	0	0	0	0	0.8
25	0	0.3	1	0.5	0	0	6.6	0	1.2	0.4	0	0.4	0.8	0	0	0	0	0	0	0.2
26	0	0	0.3	0	1	0	1.4	0	1.7	0.6	0.2	0	0	0	0	0	0	0	0	0.4
27	0	0	5.3	0	0	6.3	0.2	0.4	0	0.4	0.4	0	0.6	0	0.2	0	0	0	0	6.8
28	2.8	0	5.8	1.3	0	0.5	1	0	0	0.4	4	0	0	1.3	2.5	0	0.2	0	2.8	0
29	0	0	2	0.3	0	0	0	0	0	0.2	7	0	0	0	0.4	0	0.6	3.2	2.4	0
30	0	0	0	0	0	0	0.3	0.8	0	0.4	1.4	0	0	0	0	0	0	29.6	1	2.6
31	0.3	0	1	0.5	0	1.3	0	0.2	0	0	1.3	0	0	0.2	0	0	0	5	0	0.2
32	0	0	1.5	2.3	0	0	0	0	0	0	0.4	0	0	0	0	0	0.6	0	2.2	0
33	1	0	0.5	3.8	0	0	0	2	0	0	0	0.4	0	0	0.4	0	0	0	0	0
34	1.3	0	0.3	0.5	0	0	0.8	1.3	0.6	0	0	0.4	0	0	0	0	0	0	0	0
35	3	0	6.1	0	0	0	0	2	0	0	0	0.7	0	0	0	0	0	0	0	0
36	1.5	0	0.5	0	0	0.5	0	1.8	0	0	1	0	0	2.2	0	0	0	0.4	0	0
37	0.3	0	0	1	0	0	0	4.1	0	0.9	0.8	0	0	0.2	0.2	0	2	0	0	0
38	0.5	0	0	0.3	0	0	2.8	5.5	0	2.2	0	0	0	0.4	0	0	1.4	0	0	0
39	5.6	0	0.3	0	0.8	0	3.3	1	0	0.8	0	0	0	1.5	0	0	1.8	0	0	0
40	0	0	0	0	1.8	0	0	1.2	0	0	0.5	0.8	0	0	0	0	0.7	0	0	0
41	0	0.8	0	6.6	0.3	0.8	0.4	1.4	0	0	1.3	0	1.2	0	0.4	0	0	0	0.6	0
42	0	1.5	0	0	0.3	0	0	0.7	0	1.8	1.4	0	0	1	0.4	0	0	0	8.6	0
43	0	0.5	1.3	3	0	1.3	0	3	0	0	0.9	0	0	0	1.4	1	0.8	0	0	0.8
44	0.3	0	1.3	0	0	0	0	2	0	0	0	0	0	0	0	0.2	11.8	0.6	0	0.2
45	0	0	0	0	1.3	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0.8	0
46	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	1.3	0	0	0	4	2.6
47	0.3	0.8	0	0	0	4.1	0	0	0	0	0	0	0	0	2	0	0	0	3.7	0
48	0	0	0	0	0.5	0	0	0	0	0	0	0.2	0	0.2	0	1.4	0	0	0	1.2

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
49	0	0	0	0	0.5	0	0	0	5.8	0.4	0	0	0	0	0.2	0	0	0	0	0
50	0	0	0	0	0	0	0	0.2	6.3	0	0	0	0	0.8	0	0	0	0	0	0.7
51	0	0	0	0.8	0	0	0	1.8	2.2	0	0	0	0	0	0	0	0	0	0	5
52	0	0	0	0	0	0	0	1.2	2.8	0	0	0	0	2.2	0.3	1.4	2.2	0	0.6	0
53	2	0	6.9	0	0	0	0	0.2	0	0	0	0	1.2	3.6	0	1	0	0	0	3.4
54	0.8	0.5	0	0	0	0	0.8	1	0	0	3.2	0	0	0	0	1.2	0	2	0	0.2
55	0	3.8	0	0	0	0	3.1	0	0	0	1.4	0	0	3.8	0.2	0.6	0	0	0	0
56	1.8	0.3	0	0	0	0	0	0	0	1.6	0.4	1	0	0.8	1	0	0	0.4	0	0
57	1.8	0.3	1.3	0	8.6	0	0	0	0	0.2	0	2	0	0	0	0	0	5.2	0	0
58	4.8	4.3	4.6	0	5.3	0	0	2.8	1.2	0	4.8	6.6	0	0	0	0.6	0	2.2	0	3.8
59	2.3	0	0	0	3.8	0	0	4.5	0.7	0	0	1.4	2.1	0	0	0	0	0	0	1.4
60	0	0	0	0	1	0	0	0	0	0	5.7	0.8	0	4.2	0	0	0	0	0	0
61	0.8	0.3	2.5	0.8	1	0.6	0.4	1.1	5.2	0	4.2	0	0	0.2	0	0.2	0	0	0	2.2
62	0.3	0	0	1	0	0	0	0	2	0	0.6	1.6	0	0	0	0.4	0	0	0	2
63	0.5	0	0.3	0	0	0	0	0	0	0	0	0	0	0	2.6	0	0	0	0	2.6
64	0.5	0	0.5	0.3	0	0	0	0	0	8.7	0	0.2	0.4	0.2	3.6	0	0	0	0	0.2
65	1.3	0	0.3	0.3	0	0	0	0	0	0	0.2	0	0	0	2.1	0	0	0.4	0	0
66	0	0	0	0	0.3	0	0	0	0	0	3	0.8	0	0	11.7	3	0	0.4	0	3.2
67	1.3	0	0	0.5	0	0	0	0	0	0	0	0.6	0	0	2.8	0	0	0	0.4	1
68	1.3	0.5	0	0	1.8	0.2	0	0	4.5	0	0	0	0	0	0	0	0	0	0	0
69	5.1	1	0	0	4.3	4.1	0	0	0	0	0	4.6	1.6	0	0	0	0.8	0.4	0	1
70	0	0.8	0	0	0	0	0	0	0.2	0	15.1	0	3.1	0	0	1.4	0	3.9	7.5	0.2
71	0	0.5	3	0	0	0	0	3.4	0	0	0.2	0	0	0	0	0	0	0	2.2	0
72	0	0	13.7	0	0.5	3.4	0	0	1.6	0	0	0	1.7	0	0	4	0	0.2	0	0
73	0	0	4.3	0	0	0	2.3	0	0.6	0	0	3.1	0.4	0.2	0	5.6	0.4	0.2	0	0
74	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.8	0	0
75	1.8	0	0	0	0	0	0	0	0	2	0.2	0	0	0	0	0	0	0	0	0
76	0	0	2.3	1.5	0	0.2	0	0	0	0	2	0	0	0	0.4	0	0	0	0	0
77	3	0	0	0	0	0	0	0	0.8	0	0.6	0	0	0	1.4	0	0	0	0	0
78	6.9	0	0.5	0	0.5	0	0	0	0	1.4	0	0	0	0	0	2.6	0	0	1.8	0
79	0	0	0	0	0	0	0	0	0	0.8	0	4.3	0	0	0	5.2	0	0	3.4	0
80	0	0	1	0	0	1.6	0	0	0.4	0	0	1.6	3.3	0	0	0	0	0	0.4	3.4
81	0	0	0	0	0	0.3	0	0	0	0	0	0	0.4	0	0	0	0	0	0	5
82	21.3	0	0	0.8	0.8	0	0	0	17	0.6	2.4	0.4	2	0	0	0	0	0	0	0
83	0	0	0.8	0.5	0	1.1	0.4	0.3	0	0	0	0.6	0	0	9.9	0	0	0	0	0
84	0.3	2.3	1	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0.2	0.4	0	0
85	0.5	0	1.3	0	0	0.3	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0
86	0	0	0	0	0	0	0	0.3	0	0	0.2	0	0	0	2	0	5.2	0.2	0	0
87	0	0	0	0	0	0	0	0	0	0.2	0.7	0	0	0	0.2	0	0.8	0.2	0	0
88	0	0	1.5	0.8	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0
89	0	0	0	8.4	0	0	2.6	2.6	0	0	0	0	0	0	0	0	0	0	0.2	0
90	0	0	0	1.5	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	2.8	0	0	0	8	8	0	0	0	0	0	0.8	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	1	0	0	0	0.8	0
93	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0.4	0	2.2
94	0	0	0	0.3	0	0	0	0	0	0.2	0.2	0	0	0	0	0	0	0	0	0
95	0	0.3	0	1	0	0	0	2.3	0	8	0.2	0	0	1.1	1.4	0	0	0	0	0.2
96	0	0.5	4.3	2	0	0	0	2.1	0.2	0.2	0.2	0	6	0	0	5.2	0	0	0	39.8

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
97	6.4	0	0	0.3	0	0	0	0	1.1	0.2	0	4.2	0	0	0	0	0	2.6	8	0
98	0	0	0	6.6	0	0	0.4	0	0	0	1.1	0	0	0	0	16	0	0	2.6	0
99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0
100	0	0	0	0	0	0	0	3.4	0	0	0	5	0	0	9.4	0	0	0	0	0.6
101	0	0	0	0	0	0	1.2	10.6	0	0	0	0	0.6	5.2	0	0.2	0	0	0	0
102	0	0	5.6	0	0	0	1	0.2	0	4.8	0	0	0	0	0	0.8	0	0	0	0
103	0	20.6	2.5	0	11.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0
104	0.5	0	0	0	0	0	0.6	0	0	0	8.2	0	0	0	0	0	0	0	0	0
105	3.8	0	0	0	0	0	1	0	0	0	2.6	0	0	0	0	0	0	3	2.6	0
106	0	0	0	0	0	0.8	0	1.4	0	0	0	0	0	1.4	3.6	0.2	0	2	0	0
107	0	0	0	0	0.8	0	1	3.6	0	0	0	0	0	0.6	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0	0	1.2	0	0.9	0	0.2	0	0	0	0	0
109	0	2.8	0	11.9	0	0	0	0	0	0	0	0	3.4	0	0	0	3	0	0	0
110	3	0	3.3	0	0	0	0	2.4	0	0	0	0	0	29.6	0.2	0	0.2	0	0	0
111	10.2	0	0	0	0.5	0	0	0.2	0	0	0	0.4	0	9	0	0	0	0.8	0	0
112	9.1	0	0	0	0.3	0	0	0	0	0	0	1.3	0	1	7.4	0	0	0.6	0	0
113	0	2.8	0	0.3	0	0	0	0	0	0	1	0	0	0	0	0	0	3.2	21.2	0
114	0	0	0	0	0	0	0.6	0	0	3.4	0	0	0	0	0	0	0	0	5.4	0
115	0	0	0	0	0	0	0	0	0	0	0	1	0	2.2	3.6	0	0	0	0	0.4
116	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.8	0	0	0	0	0
117	0	2.5	0	5.3	0	8.6	0	0	0	0	0	0	0	0.2	0.4	0	0	0	0.6	0
118	0	8.9	0	0.3	0	0	14.6	0	0	2.3	0	0	0	0	4.8	0	0	0	0.2	1.4
119	2	1	0	0.3	0	0	0.4	0	0	0	0	0	0	0	2.2	0	5	0	0	0
120	0	0	8.1	1.8	0	5.6	0	0	0	0	0	0	0	0	0.4	0	5.6	0	0	0
121	0	0	3.8	0.3	0	0	0	0	0	4.8	0	0	0	0	0	0	0	0	0.2	0
122	0	0.3	0	0	0	0	4.4	2	5.4	0	0	0	0	0	0	2.2	0	0	0.6	0
123	2.8	0	0	0	0	0.4	0	1.5	0	0.2	0	0	11.6	2.8	0	0	0	0	0.8	0
124	3.8	0.8	0	6.1	0	7.2	0	6.9	0	0	0	0	4.6	2.6	0	0	0	0	0	0
125	7.6	0	0	8.1	0	18	0	0.3	0	0	1.4	1	0	0	0.2	0	0	0	0	0
126	0	1	0.8	4.3	0	0	0	0	0	6.8	0	0	0	0	0	0	0	0	0.2	0.6
127	0	0.3	1.3	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.4	0.6
128	0	1.3	0.5	0	0	0	1	0	0	0	0	0	2.4	0	0.2	0	0	0	0.4	7.6
129	0	0	16.5	0	0	0	4.7	0	0	1.8	0	0	13.9	0	0.8	0	0	0	0.6	6.4
130	0	0	6.9	0	0	9	2.8	0.6	0	0	0	0	0	0.2	0.4	6.4	0	0.8	0	0
131	0	0	0	0	4.3	19.3	2.3	0	0	0	0	0	0	2.2	0.2	0	0	2.6	0	0
132	0	0	9.9	0.3	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0.6	0	2.4
133	0	0	0.8	0	0	0	0	0	0	0	0	1.6	0	0	19.8	0	0.6	0	0	47.4
134	0.5	0	0.3	0	0	0	0	0	0	3.4	0	0	0.4	0	10.8	0	6.4	0	2.2	14.6
135	3.8	0	0.3	3.3	0	21.8	9.6	0	0	0	0.2	0	2	0	0	0.6	0	0	0	0
136	0	0	1	0.3	0	10.8	4.4	19.7	0	0.8	0	0.4	6	0	0	0	0	2	0.4	0
137	13.5	0	0	0.8	0	0.2	0	0.4	0	0.6	0	0	0.6	0	0	0	0	8.2	0	0
138	9.9	0.3	1.5	0	0	1	0	1.4	2.6	0	14.6	0.2	0	0	0	5.8	0	0	3.8	0
139	0	0	1.3	0	0	0.2	0	0	0	0	2.8	0.2	0	0	0	38.8	0	35	0	0.2
140	0	7.9	0	0	1.8	0.6	0	0	0	0	0	3	0	0	0	0	0	5.2	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	4.8	0	2.6	0	0	0.2	3.4	4.1
142	0.5	0	0	0	0	3.1	0.2	0	0	0	1.5	0.2	0	0	0	0	0	3	0	0
143	0	0	2.5	5.1	0.3	0	0	0	6.3	1.2	7	0	1.6	0	0	0	0	5.2	11.2	0
144	8.1	0	0.5	4.1	1	1.7	0.4	1.8	2.4	0	0	0	3.9	7.8	0	0	0	4.2	6.7	7

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
145	5.8	0	0.5	3.8	0	0	21.3	0	8.2	0	0.4	0	0.2	3.4	0	0	0	0	0	2.8
146	0	1.3	0.8	0	0	9.1	4.1	0	12.4	2.2	0.2	0	0	0	0	0	0	0.2	0	0
147	0	9.7	0	0	0	0	0	0.6	4.2	0	0	0	9.4	0	0	0	0	0	0	1.6
148	0	14.5	0	0	4.6	30.7	0	0	2.2	3.2	0	0	0	10.2	0.4	6.2	0	0	0	0
149	0	0	0	2.3	0.5	5.2	5	1.4	0	0	0	0	0	4.2	0	14.8	0.8	0	0	0
150	0	0	0	0	2	0	9.2	0	1.4	0.2	0	0	1.8	0.2	0	1.8	10.2	0	3.4	0
151	0	0	0	0	2	0	0	0	0	12	0	0.2	15.5	3.2	0	0	0.4	1	0	0
152	0	0	0	0	0	0	0	0.2	8	0	0	2.2	4.2	0	0	0	0.6	3.8	0	0
153	0	0	0.3	0	0	2.8	0	0.2	0.2	0	0	0	0	0	0	1.6	0	1.2	0	7.6
154	0	0	0	5.8	0	0	0	5.4	8	16.4	0	0	0	0	0	0	0	0	0	0
155	0	0	19.3	1.5	1.3	0	0	0	5.6	0	0.2	0	0	0	0	0	0	0	10.8	0
156	0	0	1	0	0	0	9.6	0.8	1.4	0	4.8	2.2	4.2	0.8	0	5	9.2	1.8	0.4	0
157	0	0	0	5.1	0	0	0.8	6	0.4	3	0	4	26.4	1	0	0	0	5.4	0	0
158	0.3	0	3.6	0	0	2.9	0	0	0	0	0	0.4	24.8	2.2	1.8	0	0.2	0	0	23.3
159	8.1	2.5	1	0	1	0	1.6	1.8	0	0	0	0	1.2	2.8	18	0	37	0	0	10.4
160	7.9	0	1.5	0	10.4	0	3	0	0	0	0	0	0	0	0	6.2	13.8	10.4	0	0
161	1.8	1.8	0	0	0	0	0	0	0	9.2	0	0	0	0	1.8	5	15	0	4.4	3.8
162	17.3	0	0	0	6.6	0	0	0	1.6	3.6	0	0	0	0	2.6	0	15.4	0	2.6	19.6
163	0.3	0	0	0	0	0	0	0	0	0	0	0	8.8	0	0	0	0	0	7.8	0
164	1.3	0	0	6.6	3.8	1.6	3.1	9.2	0	0	0	1.6	0	7	0	0	0	0	2.6	0.8
165	0	9.1	0	0.3	0	0.4	7.7	29.9	0	0	0	0	0.6	4.8	0.6	0	0	1.2	0	0
166	0	39.4	0	3.3	0	0	2.4	2	0	0	0	0	2	8.8	14.8	0	1	0.4	0	0.4
167	1.5	12.4	1.3	0	0	1.3	2.2	0	4	2.8	0	0	0	0.2	0	5.4	0	7	2	2.8
168	10.2	0	0	2.5	0	0	0	0	19.1	4	0	0	0	0	0.4	0	0	0	0.4	5.9
169	9.7	2	0	0	0	0	0.2	0	2.2	0	0	26.4	3.1	0	0.4	0	11.8	0	1.4	1.6
170	0	0.5	0	0	21.6	0	0	0	13.7	6	0	42.2	3.2	1.8	15.8	0	0.4	1	0	0
171	0	1.5	0	1.5	3.6	0.5	0	1	0	4.5	0	11.4	0	12.4	0	1.2	1.8	0.4	0	0
172	9.7	0	0	0	0.3	0	20.2	0.5	0.8	0.2	0	1.8	0	7.8	0	3.6	0.2	3.6	0	14.8
173	5.1	0	9.9	0.8	10.9	0.4	1.4	0	0.7	0	4	0.2	0	0	0	0	7	2.6	0	0
174	0	0	0	0.5	4.1	0	0	3.4	0.6	0	0	0	0	25.5	5	0	7.4	0	0	1
175	30.2	45.2	0.5	0	3.3	0	0	8	13.1	0	0	39.8	2	9	5.4	0.8	11.2	0	2.4	4.9
176	0.3	19.6	0	0.3	0	1.2	0	0	0.7	0	0	42.5	3.4	0	6.2	0	0	0	2.8	0
177	0	0	80	11.7	21.6	0	0	0	5.4	0	0	0	0	0	0.6	0	3.4	8	11	0.2
178	2	0	3.8	38.1	2.3	0	0	0	17	0.4	1.8	3.2	0	0	0	4	1.2	31.6	0.8	1
179	6.9	0	1	5.3	0	6.1	0	0	2.4	0	0	5.6	0	0	0	0	17.6	1.8	3.8	1.8
180	0	7.4	0	2.5	0	1.6	17.6	0	0.5	0	0.8	0	0.8	0	0	0.8	0.2	2.4	0	3.8
181	0	6.1	0.5	0	0	0	8	3.1	1.8	2.2	1.4	4.8	0.2	0	0	6.4	3	0.8	0	0.2
182	3	4.1	4.8	0	8.1	14.9	0	28.6	0	0	0	2	0	0.2	0	0	0	0	12.2	0.2
183	0	0	6.9	0	0	4.2	0	16.1	0	0	37.9	0.4	0	0	7.6	0	0.2	2.6	26.6	0
184	0	0.3	0	0	0	2.9	0	0	9	0	30.2	0	0	0	4.2	0	16.2	2	85.4	0.8
185	0	0	0.3	0	0.8	0	0	0	0	0	34.1	3.4	1.2	0	3.8	0	0	3	0	2.2
186	0.5	2.8	22.9	0	0	18.3	0.6	0	5.4	0.6	5.5	4	12.8	0	4.6	5	37.4	6.6	0	0
187	5.3	0	1.3	0.8	0	39.2	0	5.5	1.2	4.4	1.4	26.2	8.4	0	0	7.6	59	0	16.8	0
188	0	0	2	0	0	2.6	1.6	3	0	33.8	0	1.8	0	0	0	0	0	5.8	0	3.8
189	1	4.8	3.6	0	0	0	0	0	0	0	5	2.2	0	0	3	2.4	0	25.6	0	0.6
190	0.5	0	9.7	0	1.3	13	0	0	0	0	0	0	0	0	6.2	12.8	0	0	0.4	0
191	0.8	0	0	0	0	0.6	21.2	3	0	0	0.2	0	0	0	0.2	0	2.4	11.8	0	0.6
192	0	0	26.7	0	0	1.9	66.8	48.4	0	0	3.8	0	0	4.8	1	0	5.2	8.6	0	0

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
193	1.5	0	30.2	0	0	0.6	0	17.9	1.1	0	0	0	11.6	4	2.8	2	1.4	0	0	0
194	3.3	0	0	1.8	0.3	0	2	10.5	0	0	0	0.2	2.6	0.4	7.8	0	2.4	0	0	0
195	0	0	0	6.9	3	0	0	4.8	0	55.8	10	0.4	0	0	1.4	0	12.2	0	0	0
196	0.3	1	0	0	0	5.1	0	0	1.2	2.8	4	5	0	2.6	6.6	0	0	0.2	0	0
197	0.5	0	0	1.3	0	0	3.6	0	0.4	0.3	1.8	16.4	0	18.6	7.2	6.6	0	7.4	8.6	0.8
198	0	1.3	0	3.6	0.3	6.6	0	0	1	0	1.8	0	0	0	42.4	3.6	0	0	0.2	2.8
199	0.8	0	0	14.5	3.6	2	0.2	0	0	0	2.6	0	6.6	0	8.2	0	1.2	0.8	0	0
200	0	0	0	0.8	0.8	0.8	2.2	0	1	0	3.8	1.4	0	0	0	6.6	0	0	1	0.6
201	0	0	0	0	0	0	0.2	0	0	0.2	0.2	2.6	1.2	0	0	4.6	0	0	0	0
202	0.3	2	0	1	0	0	0	1.4	0	0	2.8	10	0.7	0.6	0	5.2	0	2.5	0	0
203	2.3	4.6	0	0.3	0	0	0	0	13.6	11.7	30.6	0	0	0	0	1	0	0.2	0	0
204	0	11.9	0	0	0	4	4.6	0.5	0	0.4	0	0	0	3.2	11.4	1.4	0	0	0	0
205	0	3.6	3	0	0	0	1.6	0	0	0	0	0	0	2.8	0.6	0	0	4.2	0	0
206	4.1	0	0.8	0	0	0	0	0	1.4	0	0	0.2	0	0	0	4.4	0.2	0	0.2	0
207	0	0	3.6	0	0	0.4	0	0	0	0	0	0.6	0	0	0	0	0	0	0.2	1.7
208	5.8	25.1	0	0	4.3	0	6.7	0	0	0.2	0	0	0	0	0	0	1.2	13.2	0	0
209	11.9	0	0	0	0	6.8	0	3	7.6	3.4	0	0	0	0	0.6	0	0	0	0	0.4
210	0	0	0.5	2.8	0	16.3	12.3	39.1	2.6	17.8	0	0.6	0	0	0	0	0	0	0	0.2
211	0	0	10.2	0	5.6	1.2	0	0	0	0.4	0	0	0	0	4.2	6.2	0.9	1.2	0	0
212	8.6	0	0	0	1.5	0.2	1	0	0	0	0	0	0	1	0	52	0	0	0	0
213	0.3	0.5	0.3	1.8	59.7	0	0.8	0	0	0	0	0	0	0	0	8.6	0	0	0	0
214	0	4.3	0	6.4	0	2.4	0	0	6.7	0	0	0	0	0	0	3.6	0	0	0.8	0
215	10.9	0	0	3.8	0.8	2.2	0	6.7	35.4	10	0	4.4	0.6	0	7.8	0	0	4.2	0	0
216	8.4	15.2	0	0	8.4	0	0.7	0.2	0	0	7	0	0	1.3	0	14.8	0	2.2	0	0
217	7.4	31.8	4.1	7.9	0	2.6	4	0.7	0.2	0	0	3.2	0	0	8.6	8.2	0.8	0.4	0	0
218	0	16.8	1	1.5	0	0	0	0	7.2	0	0	0	3.2	0	0	0	24.2	0	0	7.3
219	0	11.4	0.5	0.5	0.3	0.9	0	0	0.8	0	0	0	0.4	2.2	0	0	0	0	0	0
220	2.3	0	0	0	5.3	15.2	0.5	25.8	0	0	0	0	0	30.4	0.4	1	0	0	0	0
221	11.2	0	1.3	0	6.1	0.4	0	0	0	0	0	0	0	0	0	1.6	2.8	0	0.8	0
222	2.8	3.6	1.8	0.5	0	0	0.2	0	2.4	0	0	0	0	1.6	0	4.6	0	0.2	0	0
223	16.3	0	0.8	14.2	0	0.6	1	0.2	0	0	3	0	4.8	6.4	0	4.8	0	0	0	26.3
224	0	0	0	0	2.3	0	4.2	0.8	0.2	0.2	1.4	0.2	0	0.2	0	1	0	0	0	10.2
225	2.8	0.5	0	0	0	0	0.5	0	0	0	0	0	3	0	0	0	0	0	0.2	28.6
226	0	0	0.5	0	0	0	1.2	0	1.4	0	3.2	0	0.4	13.2	0	0	4.8	0	0	0
227	0	0.8	0.3	0	0.3	2.7	1.8	0	0.4	0	1.4	0	1.6	5.4	0	0	0	1	0	0
228	0	0	0	0	0	0.8	38.9	0	2.8	0	0.8	0	0	0	0	0.6	0.6	7	33.6	0
229	0.5	6.6	0	12.4	21.3	0	1.7	0	3	0	0.2	1.6	0	0	0	1	0	4.8	0	0
230	0	0	0	5.6	0	0.8	1.8	0	0.6	0	0	0	0.8	0	0	2.3	22.6	11.2	0.2	0
231	0	0	8.9	0	3	0	11	0.6	0.9	0	0	3.2	0	0	0	0	0	0	0	0.2
232	0	0	0	3.6	0.8	1.6	5.6	0	1	0	0	0	4.8	7.5	0	13.4	27.8	0	0	5.6
233	0	0	0	29.2	0	1.8	0	0	0	0	4.6	0	0	2.4	0	0.4	12	0.2	0	0
234	0	0	0	0.5	0	0	0.8	0	0.4	0	0	0	0	0	0	0	0	2	1.2	0
235	0	0.5	0.3	0.3	0.3	0.5	12.6	0	0.6	0	2.2	0	0	0	0	0	0	0	0	41.6
236	0	0	8.4	1	0.8	5.6	0	0	34.6	0	2.8	0	3.4	0	0	3.6	0	2	0	0
237	0	0	0	0	6.4	1.2	5.2	1	0	0	3.6	0	0	0	1.4	0	0	0	0.4	0
238	0	2	0	0	16.5	0	0	0	0	0	0	0	0	0	0	0	0	1	6.4	0
239	0	1	1	0	0	0	0	2.4	1.4	0	4.8	0.6	0	0	0	0.8	0	0	0	0
240	0	0.3	0	9.4	0	0.7	0	0	52.5	0	0	0	0	0	0	3.6	0	1.4	0	1.2

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
241	0	0	0.3	19.6	0	21.9	0	0	0	3.8	7.3	0	0	0	0	0.2	0.6	8	0	0
242	14.5	5.8	0	1.3	0.8	3	0	1	0	10.2	10.2	0	0	5.2	0	0	1.2	3.2	13.4	0
243	0	0	0	1.8	0	9.1	0	1.5	1.2	0	0.4	0	0	0.2	0	0	0	0	15.2	0
244	0	0	0	0	0	0	1.4	0	0	0.4	0	2.8	2	0	0	0	0	0	0	0
245	0	0	0	0	5.3	0.5	0	0.4	0.4	0	0	5	0	0	1.4	42.6	0	3.8	0	0
246	0	0.5	0	0	0	0	0	0	0.6	0	0	0.8	0	0.4	0	23.6	0	0	2.4	0
247	0	0	0.8	0	0	0.2	0	1	0	0	15	0.4	0	1	0	0	0	7.8	0	0.6
248	8.4	0	3.3	0.3	5.8	0	0	0	0	0	2.8	6.5	0	1.6	0	0	0	1.4	3.8	0
249	0.5	0	4.3	0	9.4	0	3	0.4	0	0	0	0	25.5	1.2	0	0	2	0	4.4	0
250	0	2.5	0	0	0.8	1.6	16.5	0	3.4	0	0	0	20.1	2.6	0	0	0.6	1.2	0	6.8
251	0	0	3.3	0	0	0	36.7	1.2	0	0	0	15.8	1.2	0	0	0	0	3.2	1	0
252	0	0	7.4	0	0	0.8	0	5.8	0	0	7.4	0.6	17	0	0	0.6	4	3	0	0
253	0	0	11.2	5.1	0	0	1	1.8	0	0	0.8	0	1.8	0	10	0	9	0	0	0
254	0	17.8	0	0	0	0	11.2	0.2	0	0	0.6	0	0.9	0	38.6	0	0	0	0.4	0.2
255	0	5.3	0	0	7.4	0	0	0	2.4	0	0	0	0.8	2	0	0	0	0	0.2	0
256	0	1.3	0	0	0	0.2	0	0	9.8	0	0	0	0	11.4	0	0	0	0	0	0
257	0	0	0	0	0	10.8	0	0	0	0	0	3	0	0	0	0	0	0	0	0.2
258	1.5	0	2.5	0	0	5.9	16.9	0	0.8	0	0.4	0.2	0	0	0.2	0	0	0.6	0	0
259	0	0	0	0	0	0.4	7	0	18.2	0	0	3.5	0	5	0	0	22.4	5.4	1.2	2.8
260	0	0	0	1	0	1.5	10.7	0	2	0	0	4.4	0	0	0	0	0	0	0.4	0
261	0.8	0	0	0.5	0	0	4.4	2	0.6	0	0	0	0.4	0	0	0	0	0	0	0
262	15	0	0	0	0	0	0	0	0	5.8	0	0	0	0.4	0	0	3.8	0.6	0.2	0
263	2	5.8	0	0	0	1	0	0	0	8.6	0	0	7.8	0	0	0	0	0	0	0
264	5.3	0	0	0	0	0.7	0	0	3.4	0	0	0	14.6	6.6	0	0	0	0	0	2.4
265	0	0	0	0	0	0.2	0	0	1.6	11	0	0	7	1.8	0	0	0	0	0	0.2
266	0	4.1	0	0	0	0	0	0	1	0.2	0	0	0.8	3.2	0	0	0	0	0	0
267	0	0	0	0	0	0.2	0	0	0	4	0	0.2	1.6	3	0	0	0.8	0	0	0
268	0	0.8	0.5	0.5	0	7.6	1	0	0	0.6	0	0	0.4	0	3.6	0	4.4	0	0	0
269	0	0	1.3	0	0	5.3	0	0	0	0.6	0.6	0	0	4.4	23.6	0	0.2	0	0	0
270	0	0	3.8	0	0	0.4	0.6	3	0	0.8	0.2	0	0	0	7.4	0	0.4	0	0	0
271	0	0	2.3	1	0	0	1.8	5.6	0	0	2	0	0	0	3	0	0	0	0	0
272	4.1	0	4.3	0	0	0	0	0	1.4	0	0	0	0	0	1.2	0	0	0	0	0
273	0	9.1	0.5	0	0.3	0	0.3	0.4	0	0	0	0	0	0	5.6	0	0	0.8	0	0
274	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	7	0	0	0	0	0.6
275	0	0	1	0	6.1	0	0	0	0	0.2	2.6	0	0	0.4	0	0	0	0	0	0
276	0	0	0	0	0.3	0	3.9	0	0	0	3.8	0	0	0.8	4.2	0.6	0	0	0	0.4
277	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	5.4	3.2	0	0.4	5.6	0
278	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	7.8	0
279	0	0.8	0.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
280	0	8.4	0	2.5	0	0	0	1	0	0	0	1	0	0	1.8	0	0	0	1.8	0
281	0.5	0	0	0.3	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0
282	0.3	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0
283	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	1.4	0
284	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0.8	0	0	0	0	3	0
285	0	0	0.3	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0.6	0
286	0	0	1.5	0	3	0	0	0	7.2	0.2	0	0	0	7.4	0	0	0	0	0	0
287	0	0	0	1	0	0	0	5.6	1.7	0	0	2	2	8.5	0	0	0.4	0.8	0	0.4
288	0	0.3	0	0	0	0	0	1.4	0	0	0	0	0	4	0	0	0	0	0	0

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
289	0	0.5	0	0	0	0	0	0	0	0	0	0	13.4	1	0	0	0.2	0	0	25.2
290	0	0	0	0	0	0	0	0	0	0	15	0	8.6	0	0	0	0	0	0	0.2
291	0	4.8	0	2.3	0	0	0	0	0	0	0	0	24.2	0	0	0	0	0	0	0
292	0	0	0	0	0	0	0	0	0.4	0	0	0	0.2	0	0	0	1	0	0	2.6
293	1	0	0	0	0	0	9	0	0.2	0	0	0	0	0	0	0	0	0	0	0
294	6.9	0	0	0	0	0	1.6	0	0	0.4	0	0	0	0	0	0	0	0	0	21.2
295	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
296	3.3	5.1	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0
297	0.5	6.1	0	0	0	0	0	0	0	0.4	0	0	1.4	0	0	0	0	5.6	0	0
298	0	2.3	0	0.3	0	0	0	0.8	1.2	1.5	0	0	0.6	0	0	0.8	0	2.8	0	0.8
299	0.3	1	0	6.4	0	0	0	0	4.1	0	0	1.6	0.2	0	0	0	0.8	0	2	3.2
300	0	0	0	0	0	0	0	0	0	0	0	13.2	0.7	0	0	0.2	0	0.4	0	0.2
301	0	0	0	0	0	0	0	0.4	0	0	0	0	1	5.8	1.3	0	0	0.2	0	0
302	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0
303	0	0	0	0	0	0	0	0	0	0	0	0	5.9	0	0	0	0	1.2	0	1.4
304	0	1	0	0.5	0	0	0	0	0	0	0	0.2	0	0	0	0.2	0	0	0	1.4
305	0.5	1.5	0	0	0	1.8	0	0	0	0	0	0.2	2.3	0	0.2	0	0.4	2.8	0	0
306	3.6	1.5	0	0	0	0	0	0	0	0	0	0	1	0	5.2	0	0	1.4	0	0
307	0	0.3	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0.2	0	2.4	0.2	0
308	0.3	1.3	0	0	0	0	8.8	0	0	0	0	0.2	0.4	0	0	0	0.4	1.4	0.6	2
309	5.6	4.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.4
310	0.3	2	0	0	0	0	0	0.4	0.4	0	7.6	0	0	0.6	4.2	0	0	0	0	0
311	0	0	0.5	0	0	0	7.2	0	0	0	0.4	0	0	1.2	5.8	0	0.2	7.6	0	0.2
312	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.8	1.4	0	0	0.4	0	0
313	0	5.3	0	0	0	0	1.3	0	0.4	0	0	0.8	0	3.5	0.2	0	0	1.4	0	0
314	0	0.3	0	0	0	0	0.3	0	0	0	0	0.6	0	0.2	0	0	0	0.8	0	0
315	0	0	0	0	0	0	0	0	0.4	0	0.3	0.8	0.2	0	0	0	0.2	0	7.4	0
316	0	2.3	0	0	0	0	0	0	0	0	0	0	6.2	0	0	0.4	3.2	0.6	0	0
317	0.3	5.3	0	0	0	0	0	0	0	0	0	0	2.6	0	1.2	0	0	0	0	0.8
318	0	0.8	0	0	0	0	0	0	0	0.2	0	0	0	0	0	2.6	0.2	0.6	0	0
319	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	0	1.5	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	1.2	0	0
321	0	0.8	0	0	0	0.6	1.4	0	0	0	0	0	0	0.6	1.9	0	0.4	4.6	0	0.6
322	0	0	0.8	0	0	2.8	0	0	0	0	4.6	1.8	0.2	0.8	5.5	0	0	2	0	0
323	0	0	0	0	0	0.5	0	0	0	0	2.6	0	1.6	0.2	1.6	0	0	0	0	0
324	0	0.5	0	0	0	0	0	0	0	0	0	4.7	0	0	0	0	0	2.2	0.6	2.4
325	0	0	0.8	0.3	0.3	0	0	0	0.2	0	0.2	1.8	0	1.2	0	0.2	0	0.8	0.6	0
326	0	0.8	0	1.8	0.5	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0.8	0.2
327	0.3	0	0	0.5	1	0	0.4	0	0	0	0	0	0	0.8	0	0.2	0	0	16.8	0
328	0	0.5	0	0.5	0	0	0	0	0	0.2	0	0.2	0	0	0	0	0	0.4	0	0.4
329	0	2.5	0	0	0.3	0.6	3.4	0	0	0	0.2	0.6	0	0.2	0	0	0	0.4	0	0
330	0.3	1	0	1.3	0	5.1	0.4	5.8	0	0	0	0	0	0	0	0	0	0.2	0	0
331	0	0	0	0	0	0	2.2	0	0	0	0	3.9	0	1.2	0	0	0	0	0.2	0
332	0	0.3	0	0	1.3	0	4.2	0	0	0	0	0.4	0.4	0.2	0	0	0	0	0	3.6
333	0	0	0	0	0.3	0.4	4.4	0	0	0	0	0	1.3	0.2	0	0	0	0	0	0
334	10.4	1.3	0	0	0	0.4	0.6	0	0.2	0	0	0	0	0	0	0	0	0	0	0
335	1.3	3	0	0.8	0	0	0	0	0.9	0.4	0.4	0.2	0	0	2.4	0	0	0	0	6
336	0	0	0	5.3	0	1.9	0	0	4.6	0	0	0.2	0	0	0	0	0	0	2.2	0.4

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
337	0	1.3	0	5.3	0	7.7	0.7	0	4	0	0	0	0	0	0	0	0	0.4	0	6.2
338	0.5	0	0	9.9	1	0	0.9	0.2	8.6	0	0	1.4	0	0	0	0	0	0	0	2
339	0.3	0	0	0	1	0	0	2	0.4	0	0	0	0	0	0	0	0	0	0	0.8
340	0.3	0	0	0	9.7	3.1	0.4	1.4	0	0	0	0.7	0	0	0	0	0	0.4	0	0
341	0	1.8	0	0	3.3	4.2	0.4	0	0.6	0	0	1	0	0	0	0	0	0	0	0
342	0	0	0	0	11.2	0.3	0.5	1.4	7.6	0.6	0	0	0	0	0.2	0	1.8	3.6	0	1.4
343	1.5	0	0	0.5	0	0	0	19.6	6.3	0.2	0	0.6	0	0.2	0	0	0	1.4	0	0
344	1.5	0	0	0.5	1.5	0.2	0	2.6	2.6	7.8	0	1.9	0.2	0.4	0	0	0.2	0	0	0
345	0	5.8	0	0	5.1	0	1.6	0	0	0	0	0	0	0.8	0	0.2	0	0.6	0	0
346	0	7.4	0.3	0	0	0.2	1.4	0	0	0.2	0	0	0	0	0	0.2	0	0	0	0
347	0	5.3	0	0.5	0	0	0	2	0	0	0	1.4	0	0	0	0	0	1.2	0	0.8
348	0.8	0.5	0.3	1.5	0	0	0	6.3	0	0	0	0.4	2.9	2.7	0	0	0	0.4	0	0.2
349	0	0.3	0	0	1.5	1.2	0	0	0	0	0	1.2	7.2	8.8	0	0	0	0.6	0	0
350	0	0	0	0.3	0	0.4	0	0	2	0	0	0.2	0.6	4.2	0	0	0	2	0	0
351	0	0	0	1.3	0	0	0.2	0.4	0	0	0	0	0.2	5.2	0	0	0	0.5	5	0
352	0	0	0	0	0	0.4	0.2	0	0	0	0	0	0	2.6	0	1.4	1	0	8.8	0
353	1	0	0	0	0.3	0	0	0	0.2	0	0	0	0	0.2	0	0	0	1.4	0	0
354	0	0	0	0	0	0	0	0	3	0	0	0	8.4	0	0	0	0	0	0	0
355	1.3	0	16.8	0	0	0	0	0	5.3	0	2.5	0.8	0	0	0	0	0	0	0	0
356	4.8	0	6.9	0	0	0	2.1	0	6.8	0	0.2	2.7	1.8	0	0	0	0	0.2	1.8	0
357	0	0.5	0.3	0	0	0.2	0.2	0	0.4	0	0	0.2	0	0	0	0	0	0	0.2	0
358	3.8	0	0	0.3	1.5	0	0	0	0	0.6	0	0	2.6	0	0	0	0.4	0	1.6	0
359	0	0.3	0	0	3.3	1.8	0	0	0.2	2.6	0	1.6	3.4	0	0	0	0	2.4	0.4	0
360	0	1	0	0.3	1	0.2	0.3	0	0	2.2	0.4	0.4	2.2	0.2	0	0	0	0	0.8	0
361	0	0.5	0	0.8	0.5	0	0.6	0	0.2	0.6	0	0.8	0.6	0	0	0	0	0	5.8	0
362	0	0.3	0	0	0	0	0	0	1.7	0.2	0	0	1.8	0	0	0	0.6	0	0	0
363	0	0	0	0	0	0.2	0	0	0	0	0.4	0	0	3	0	4.6	1.6	0	1.2	0
364	0	0	0	9.4	0.3	0.2	0	0	0	1	0	0.2	0	0.8	0.3	0.6	6.6	0	1.2	0
365	0.3	0	0	0.8	0.5	0	2.8	0	0	0	0	0	0	0	0	0	1.8	0	1.2	0

TABLE C-2 MAXIMUM TEMPERATURE DATA

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	-3.3	0.6	-5.0	2.8	-11.1	-12.0	-4.3	-17.4	-5.1	-3.9	-23.1	-0.9	2.0	-1.0	-1.8	-1.1	-6.2	-6.5	3.7	-19.7
2	-6.1	-2.2	-8.9	-2.8	-14.4	-14.2	-5.4	-18.9	-4.3	-7.2	-25.0	-5.0	8.2	7.0	-3.9	2.6	-6.7	-1.8	-4.8	-16.2
3	-14.4	-23.3	-6.1	1.1	-13.9	-12.3	-11.1	-18.3	-6.9	0.4	-23.4	2.4	5.0	8.9	-6.2	-0.9	-15.7	-2.8	-5.5	-15.9
4	-2.8	-19.4	-8.3	-6.7	-12.8	-15.1	-16.5	-16.0	-9.6	3.4	-26.5	-0.5	8.5	3.0	-3.7	2.6	-14.2	-0.6	-11.8	-14.2
5	2.2	-17.2	-9.4	-5.6	-20.6	-0.6	-18.0	-6.9	-13.5	4.8	-23.8	-1.3	5.2	5.7	-8.2	-2.6	-13.9	-8.0	-3.7	-19.1
6	1.7	-16.7	-3.9	-7.8	-25.6	6.8	-19.7	-11.0	-25.6	-1.4	-16.3	-2.0	2.8	3.4	-5.8	-2.2	-13.3	-16.5	3.3	-23.8
7	-5.0	-22.8	-5.0	-16.1	-26.7	1.7	-22.0	-6.4	-26.4	2.0	-16.9	4.4	-1.5	-5.0	3.5	-0.4	-13.4	-19.5	2.2	-23.7
8	-4.4	-14.4	-17.2	-19.4	-20.6	-9.1	-19.5	-7.8	-25.2	-0.5	-22.0	5.2	-3.3	-6.9	8.0	-1.4	-16.7	-24.6	4.3	-23.6
9	-0.6	-9.4	-21.7	-23.9	-18.3	-13.4	-13.2	-9.1	-25.9	-3.0	-20.8	-0.1	-8.1	-13.4	3.1	0.7	-6.1	-20.4	1.9	-21.7
10	-6.7	-5.6	-25.6	-25.6	-5.6	-16.1	-11.5	-15.0	-26.0	-0.5	-20.6	-4.0	-7.3	-14.9	7.5	6.4	-13.9	-10.7	0.9	-12.3
11	-7.8	-5.0	-23.9	-21.7	-7.8	-12.2	-14.7	-20.3	-24.4	0.4	-16.9	-5.0	-6.0	-4.8	8.4	9.3	-13.7	-3.4	-3.4	-5.2
12	-27.2	-3.3	-23.9	-6.7	-11.1	-14.1	-13.2	-21.6	-16.6	6.9	-16.7	3.9	-1.5	7.7	4.3	3.2	-14.0	4.7	-5.1	-3.4
13	-28.3	6.1	-23.9	0.0	-10.6	-15.8	-4.2	-23.5	-4.6	0.3	5.1	1.6	-10.2	2.4	4.5	2.0	-10.6	5.2	0.7	3.7
14	-16.7	1.7	-25.6	-1.1	-15.0	-18.4	-11.0	-17.3	-4.6	1.1	3.9	-2.0	-11.5	-0.2	7.4	-11.2	-2.4	-7.0	2.6	4.0
15	5.6	-3.9	-25.6	-3.3	-1.1	-17.6	-12.7	-17.0	-1.4	-4.0	-24.1	1.5	-6.1	4.4	2.0	-3.6	2.2	-0.9	1.2	3.5
16	2.8	-11.1	-21.7	-2.8	2.8	-7.7	-16.2	-3.4	0.0	-0.5	-13.6	-3.0	-11.7	2.6	0.9	-3.9	-2.3	-1.0	-2.9	4.5
17	-1.1	-7.2	-7.8	3.9	7.2	-2.7	-18.6	-0.9	-2.6	-3.2	-13.8	-8.0	-19.1	6.3	-1.3	4.4	-1.9	2.3	-3.7	8.0
18	-28.9	-2.2	-0.6	0.6	3.9	4.8	-20.1	1.1	-5.7	6.2	-18.6	1.2	-12.7	-11.6	2.6	5.2	-4.4	3.3	2.8	5.7
19	-28.3	-3.3	-1.1	5.0	6.7	1.4	-17.0	1.2	-3.2	6.9	-26.4	0.0	-16.0	-18.8	-0.6	-2.6	-3.8	-0.2	1.5	-2.9
20	-23.9	3.3	-2.8	5.0	5.0	4.1	-9.0	-2.1	2.7	10.7	-29.6	-6.0	-3.9	-15.0	-4.3	4.8	3.3	6.5	5.0	0.3
21	-22.8	2.2	-8.3	0.6	-0.6	5.6	-0.9	-6.4	1.4	3.1	-26.7	-5.8	-6.6	-4.0	-5.8	-0.1	1.9	1.8	4.0	7.8
22	-22.2	3.3	-12.2	3.9	4.4	3.8	1.5	-7.2	6.4	6.1	-23.4	-6.5	3.3	1.7	-11.6	0.2	4.0	-3.2	3.0	0.7
23	-25.6	7.2	-10.6	3.9	2.2	1.9	-1.0	-0.5	8.9	6.9	-23.0	-15.7	7.0	4.7	-9.1	-1.1	2.6	-6.0	-0.5	-3.0
24	-28.9	6.1	2.8	4.4	-7.8	2.8	-0.7	-1.3	1.6	2.6	-15.1	-22.9	0.5	3.4	2.6	-6.1	0.2	-4.4	0.8	-5.5
25	-31.7	-3.3	0.6	0.6	-13.3	2.2	-11.7	-8.6	-11.2	1.0	-1.4	-17.3	-0.4	3.9	-0.8	2.3	4.8	3.9	6.4	-3.2
26	-30.0	-6.7	-4.4	-7.8	-0.6	3.6	-8.5	-7.9	-18.7	-1.7	-4.2	-13.4	-4.4	0.3	-0.9	0.7	1.9	10.2	0.7	-0.6
27	-18.3	-6.1	-13.9	-4.4	10.0	-3.6	-14.5	-3.8	-18.8	-3.6	-18.7	-12.4	8.4	-3.2	3.4	-1.4	0.2	10.7	-11.7	-0.7
28	-4.4	-7.2	-16.7	-6.7	3.9	-16.1	-14.5	-7.8	-19.6	-7.4	-14.6	-1.3	5.8	-5.0	0.6	-0.5	-3.6	7.8	-13.9	-13.1
29	-1.1	-3.3	-23.3	-10.0	5.6	-12.3	-14.9	-10.8	-18.4	-6.7	-21.0	-0.9	1.7	-18.8	-9.4	1.5	-17.9	6.8	-24.0	-3.5
30	-1.7	-5.0	-27.2	-10.0	7.8	-3.7	-15.8	-14.3	-9.7	-6.4	-12.3	-3.2	7.3	-18.5	-7.2	0.8	-21.1	4.4	-26.8	-2.5
31	-7.2	2.8	-22.8	-15.6	11.1	-6.5	-20.4	-15.0	-7.9	-5.0	-6.3	-3.0	8.1	-21.6	-2.4	3.2	-22.6	-26.7	-27.5	0.2
32	-11.7	2.2	-21.1	-18.9	5.6	3.1	-19.7	-18.5	-3.8	-8.0	-4.8	-4.9	5.0	-23.5	-1.3	-1.8	-15.3	-31.8	-23.1	8.7
33	-10.6	-1.7	-16.1	-19.4	7.8	4.8	-14.9	-19.5	3.7	-1.1	-15.9	-5.4	6.2	-21.5	3.1	1.8	-20.8	-30.1	-12.8	8.4
34	-12.2	-1.7	-11.1	-22.2	-5.0	5.9	-20.2	-18.4	6.1	2.1	-16.1	-6.9	4.2	-19.7	2.1	-1.6	-20.4	-19.6	5.1	7.5
35	-15.6	-5.6	-10.6	-22.8	-8.9	5.1	-15.7	-17.8	4.6	0.5	-15.7	-8.8	2.6	-9.5	-0.5	4.1	-22.1	-11.0	1.7	9.4
36	-16.7	-11.1	-3.9	-13.9	-2.8	7.5	-6.6	-19.0	0.7	-3.7	-2.0	-10.2	11.1	-10.6	-6.0	5.5	-15.4	-7.2	5.0	9.2
37	-18.3	-7.2	-2.2	-7.8	6.7	3.9	-5.4	-17.6	-2.3	-3.9	-1.0	-7.8	3.9	-18.1	-5.6	7.5	-13.5	-4.0	1.9	5.9
38	-16.1	-4.4	6.1	-12.8	5.6	8.1	-9.6	-19.6	3.2	-11.5	-12.1	-12.7	5.1	-21.6	-10.9	6.4	-9.4	-8.2	-2.7	7.8
39	-10.6	-6.7	5.0	-13.9	7.8	10.0	-9.7	-23.4	7.0	-13.9	-17.6	-6.7	8.8	-22.1	-12.0	6.3	-14.7	-4.3	-4.8	4.6
40	-2.8	-11.1	5.6	-12.8	0.6	7.4	-10.2	-20.9	1.4	-19.7	-8.5	-10.8	2.5	-22.8	-11.2	4.7	-20.2	0.8	-8.4	0.1
41	2.2	-12.2	7.2	-19.4	-4.4	2.7	-9.5	-22.4	-2.9	-15.4	-8.2	-8.8	7.6	-21.9	-8.1	8.9	-11.8	-1.3	3.6	4.1
42	2.2	-14.4	3.9	-24.4	2.8	3.4	-13.7	-21.2	1.9	-11.9	-11.5	-3.3	2.0	-18.0	-7.9	2.1	5.3	-0.8	-0.2	8.0
43	-1.1	-22.2	-7.2	-23.3	-1.7	4.2	-13.5	-23.4	-5.1	-10.0	-16.4	3.1	3.4	-10.4	-7.9	0.8	3.4	1.1	-17.3	3.2
44	2.2	-19.4	-15.0	-21.1	-5.0	6.3	-11.8	-23.1	-14.9	-4.8	-14.5	8.7	6.7	0.9	-11.2	-3.1	0.8	-5.8	-19.1	0.5
45	-11.7	-18.3	-4.4	-16.7	-5.0	5.2	-11.4	-24.1	-14.2	10.3	-11.0	7.0	6.6	-1.1	-4.4	-4.1	-2.5	-11.7	-11.4	-2.5
46	-6.1	-10.6	2.2	-7.8	-4.4	7.7	-10.8	-24.3	-10.0	8.8	-9.6	7.7	2.7	3.7	-13.5	-2.2	2.7	-20.6	-19.0	5.6
47	-0.6	7.8	0.0	0.6	-6.1	3.9	-5.2	-23.9	-10.2	7.9	-7.8	-7.0	2.4	2.1	-21.3	-0.5	3.5	-18.1	-24.4	4.4
48	0.0	6.1	1.1	-1.7	-4.4	7.1	0.6	-16.7	-6.9	9.3	5.5	-9.8	3.1	-2.7	-24.4	4.9	5.9	-18.0	-21.9	1.9

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
49	-6.1	2.8	1.1	5.0	-5.6	6.4	4.6	-14.4	-9.1	9.4	2.3	-8.0	4.5	8.1	-24.1	5.3	6.0	-12.6	-5.2	4.1
50	-17.2	2.8	3.3	3.3	-9.4	9.4	7.4	-9.1	-11.3	5.9	8.1	0.0	5.8	7.5	-22.2	5.5	6.1	-5.7	2.6	7.8
51	-17.8	2.8	0.6	-0.6	-2.2	9.4	10.0	-8.6	-12.2	6.6	4.5	2.1	9.8	0.7	-20.6	5.0	11.6	-3.0	5.9	3.9
52	-16.7	11.1	-0.6	0.0	4.4	11.6	8.5	-13.0	-9.2	9.2	-2.4	6.6	7.0	4.8	-12.7	3.4	7.6	-3.6	3.1	-1.6
53	-17.2	8.9	-2.8	7.8	10.6	10.0	7.8	-17.4	2.1	10.6	-4.3	4.9	4.0	1.9	-8.9	1.7	-5.5	-1.1	9.5	-3.6
54	-13.9	0.6	-1.1	8.3	9.4	5.8	3.9	-19.8	2.0	2.0	-6.4	4.0	4.4	1.6	-9.5	-3.1	-6.0	4.0	2.2	0.2
55	-13.3	-1.1	0.0	2.2	2.8	4.8	-1.6	-17.5	-1.6	0.0	-19.6	8.7	3.4	3.1	6.9	-7.1	9.5	-1.1	-0.1	4.8
56	-15.6	-7.2	0.0	-1.1	-0.6	3.6	-9.9	-14.7	9.0	-3.5	-18.6	5.6	0.4	-4.6	9.2	-7.2	13.5	-9.2	4.0	5.4
57	-23.3	-11.1	-6.7	0.0	-1.7	3.0	0.8	-9.6	0.0	-3.1	-14.5	-0.4	1.4	4.5	9.8	-7.1	13.8	-2.6	0.8	4.4
58	-21.7	-8.9	-11.7	6.1	-14.4	4.0	-6.4	-14.4	-1.9	0.2	-13.2	-6.2	-1.1	11.6	7.2	-8.7	7.9	-4.5	6.9	3.8
59	-18.9	-6.1	-6.1	-1.1	-17.8	6.2	-12.2	-16.4	-4.6	6.4	-12.6	-6.2	0.1	8.1	13.0	-4.4	9.4	-16.7	11.2	-3.7
60	-20.0	-2.8	-6.7	0.0	-18.9	5.4	-10.6	-10.4	4.6	5.3	-15.4	-4.8	1.0	-0.5	11.1	-9.0	2.2	-14.1	8.8	-19.6
61	-17.8	2.8	-7.8	-2.8	-21.7	4.4	-10.0	-9.2	-1.0	5.7	-13.9	-5.1	3.7	-9.5	11.9	-5.7	4.8	-12.2	9.6	-17.0
62	-16.7	0.6	-1.7	-3.9	-16.7	4.4	-12.8	3.6	-15.0	6.6	-13.6	-3.4	4.8	-1.9	8.3	-7.0	3.5	-10.8	10.3	-16.8
63	-11.7	4.4	3.3	-4.4	-8.9	6.6	-10.5	7.6	-10.8	5.1	-9.2	-3.9	4.1	-5.5	9.7	7.8	8.2	-13.5	6.2	-13.4
64	-10.0	4.4	-1.1	-4.4	5.0	11.6	-9.1	10.4	-2.9	1.0	-1.0	-3.4	5.7	-7.0	6.4	-2.4	9.6	-9.2	2.7	-8.5
65	-8.9	1.1	-13.9	-7.8	1.1	7.1	-4.8	10.5	-3.0	-1.0	0.1	-3.3	5.4	-4.4	-10.3	1.1	7.1	-3.8	10.2	-1.6
66	-7.2	-1.7	-15.0	-12.2	3.9	11.3	3.8	8.1	-2.2	-2.5	-8.7	-2.9	-3.4	1.1	-6.5	-2.2	9.8	-0.6	4.9	1.9
67	-13.9	3.9	-12.8	-13.3	4.4	10.2	11.2	4.1	3.3	4.3	-2.6	-2.6	-3.5	7.0	-3.3	-7.3	14.7	2.2	5.0	5.4
68	-10.0	5.6	-7.2	-9.4	0.6	7.2	9.6	5.0	0.5	9.1	1.3	4.5	8.9	6.0	8.5	-7.3	8.6	1.2	2.3	3.6
69	0.6	2.8	-7.2	-3.3	-3.9	4.0	8.2	15.0	-7.6	12.5	2.4	5.4	1.9	3.3	4.9	-8.4	6.2	-7.8	6.3	0.1
70	6.7	-0.6	-4.4	-3.3	-3.3	6.3	3.4	9.8	-5.6	10.1	0.3	6.6	-10.4	7.0	2.7	-5.6	6.5	-16.0	0.0	-7.9
71	7.8	2.2	-4.4	0.6	2.2	9.6	-1.0	4.8	-6.2	10.0	-1.1	9.0	-9.9	5.0	1.5	-3.6	6.5	-11.2	-0.6	-1.0
72	11.7	3.9	-6.1	2.8	-1.7	2.6	2.2	6.6	-8.5	10.0	4.4	3.6	-8.6	6.3	1.5	-1.8	9.3	-5.7	6.4	2.9
73	10.6	2.2	-11.7	4.4	1.1	-1.5	2.6	4.6	-8.9	11.7	2.2	2.4	-8.7	6.0	3.8	-2.1	6.8	-6.2	6.8	4.2
74	10.6	7.8	-11.1	4.4	2.8	-2.1	-0.4	12.3	-5.2	15.1	2.4	2.3	-10.4	6.6	2.3	-0.9	1.5	-10.2	8.7	2.7
75	9.4	7.8	-6.7	5.6	6.7	2.6	3.9	6.6	0.3	10.1	-4.4	1.5	-2.3	11.5	3.8	-0.7	5.3	-11.8	5.4	6.3
76	8.9	3.9	-5.0	1.7	11.7	2.5	7.3	8.6	6.4	5.8	-5.8	0.9	-3.2	13.5	3.6	3.6	8.2	-10.1	4.6	8.2
77	5.0	1.7	1.1	-2.8	8.9	-0.7	6.4	10.3	7.1	5.6	-5.2	-3.8	8.0	10.3	5.1	1.3	12.8	-8.2	8.5	10.5
78	1.7	7.8	-3.3	-2.8	2.2	-3.4	7.0	10.3	5.5	1.5	-0.4	-3.0	9.4	11.0	7.6	1.0	9.9	-5.5	10.7	8.4
79	7.2	6.1	-1.7	-2.2	0.6	3.0	11.4	8.2	6.4	-8.4	2.5	-2.5	8.4	5.1	13.5	-1.1	13.3	-5.0	0.5	8.1
80	6.1	6.7	-3.9	-1.7	7.2	-2.6	6.7	10.4	2.3	-5.5	6.6	-6.1	5.0	4.4	12.9	-1.4	9.6	-1.2	-7.4	5.1
81	6.1	5.6	-10.6	-3.9	5.6	-5.2	4.6	7.7	6.0	1.4	8.0	-4.2	11.6	2.7	6.8	-3.3	11.5	1.5	-7.6	2.5
82	1.7	7.8	-8.9	-5.6	6.1	-3.8	4.6	9.8	3.3	6.8	2.4	-4.8	13.4	3.2	5.9	0.5	9.7	6.7	-3.2	0.9
83	3.3	10.0	-6.1	-4.4	6.7	-3.4	2.4	9.4	2.4	9.4	2.7	-2.9	10.2	8.0	-2.7	8.9	8.4	5.2	6.4	-4.6
84	0.6	10.0	-7.8	-0.6	7.8	6.6	6.5	-5.7	1.7	9.9	1.2	-2.1	9.2	4.1	6.0	8.4	7.5	1.4	4.3	-3.4
85	1.1	2.2	-6.1	-3.9	7.2	8.4	4.9	-2.4	1.2	9.9	3.3	7.5	4.8	3.0	14.6	4.5	11.6	-2.0	9.6	-1.9
86	2.8	3.9	-4.4	-3.9	7.2	3.2	9.6	-1.0	5.6	13.4	4.5	7.5	10.1	0.7	15.1	-8.5	2.9	0.1	10.8	3.9
87	1.7	6.7	0.6	0.0	7.8	1.2	13.2	0.9	7.9	14.6	3.2	5.3	9.8	3.1	12.1	-2.5	0.6	-0.6	12.3	8.8
88	5.0	10.0	4.4	0.6	6.7	6.4	6.1	-3.7	6.7	9.5	4.4	6.5	11.8	5.9	10.3	6.7	2.0	7.5	15.4	11.4
89	8.3	12.2	3.3	2.2	13.3	6.2	4.5	-5.4	5.9	9.4	-6.9	3.4	11.8	8.2	11.3	13.9	4.8	9.7	12.7	11.6
90	10.0	11.1	6.1	-11.1	6.1	4.8	3.3	-5.2	5.7	13.0	-9.9	7.7	10.1	12.1	6.7	8.0	16.5	8.3	10.6	15.6
91	6.1	10.6	2.2	-7.2	6.1	2.3	0.2	1.3	5.5	6.6	-9.0	11.6	10.6	15.7	5.4	8.9	9.3	8.5	12.7	16.5
92	-5.6	11.7	0.0	-4.4	8.9	-4.0	1.6	-4.5	8.0	9.8	-12.4	9.0	12.3	8.7	7.3	17.5	8.8	9.8	13.7	14.1
93	-5.0	13.9	1.7	-7.2	13.9	11.2	5.7	-0.4	10.9	8.2	-9.6	8.7	13.1	5.9	12.3	18.7	14.0	7.8	11.6	12.5
94	5.6	8.9	6.7	-6.1	15.0	16.9	12.6	-4.6	14.2	9.2	-6.9	10.6	13.7	7.6	15.2	14.5	9.6	9.4	4.8	13.8
95	13.3	2.8	5.0	-5.0	17.8	20.9	6.2	-5.0	11.1	14.3	-3.6	12.9	13.6	5.0	14.9	13.3	10.6	7.5	10.8	9.9
96	11.7	1.1	1.7	-3.3	20.6	19.7	3.1	3.4	2.7	6.1	-3.0	16.7	13.3	5.0	14.3	12.8	13.9	8.9	10.7	3.0

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
97	6.7	7.2	9.4	-1.7	19.4	22.2	13.6	7.5	7.4	4.9	0.4	11.1	11.5	9.0	17.3	16.2	7.3	5.4	5.4	6.1
98	6.7	4.4	8.9	0.0	21.1	25.1	10.6	14.5	9.3	8.8	5.5	3.6	13.0	18.7	23.7	3.3	8.6	4.2	-0.5	8.5
99	3.3	11.1	7.2	1.7	18.9	16.0	11.3	10.4	9.2	4.4	0.6	1.1	13.0	13.6	9.6	8.1	12.2	7.7	-4.8	9.0
100	7.8	18.3	11.1	4.4	15.6	14.4	17.1	4.4	8.9	8.5	9.0	-2.7	11.8	15.3	2.8	9.1	20.4	12.6	-0.3	10.3
101	10.6	16.1	10.0	15.6	19.4	12.2	10.9	0.9	14.5	2.2	6.7	-1.8	10.7	6.7	-5.4	7.7	13.7	17.2	6.8	11.1
102	7.2	12.8	2.8	15.0	17.8	18.7	5.8	0.4	15.7	-6.8	5.7	4.5	13.5	19.0	-6.4	11.4	12.8	14.8	9.4	14.3
103	10.6	6.7	8.3	11.7	11.1	16.9	4.2	0.2	21.1	2.6	11.3	11.7	16.2	19.6	-2.8	15.5	17.1	12.1	6.5	17.2
104	12.2	1.1	8.9	4.4	12.8	11.1	2.3	2.2	13.9	14.6	4.2	12.1	21.0	13.3	4.4	16.0	20.7	17.4	15.5	13.9
105	5.0	3.9	13.3	2.8	6.7	17.2	0.8	4.4	17.8	17.6	7.5	14.6	26.9	7.4	11.8	13.4	22.5	11.5	4.2	10.8
106	5.0	6.1	13.9	6.7	1.7	10.7	7.5	3.2	19.4	13.0	9.4	13.1	28.1	12.2	6.9	18.8	14.2	-1.2	10.5	11.5
107	6.1	8.9	12.2	7.8	9.4	11.2	5.3	2.6	24.6	12.1	10.8	18.7	14.0	15.8	12.9	9.6	12.4	11.0	17.6	12.0
108	7.8	10.0	11.7	10.0	12.8	10.0	11.3	5.7	18.9	12.4	7.0	22.0	9.0	12.0	13.4	6.8	15.9	17.6	17.8	13.6
109	16.1	10.6	10.6	8.9	11.7	9.6	10.7	5.9	24.5	16.5	8.0	20.8	9.0	9.8	14.0	10.5	9.3	17.3	20.0	18.1
110	10.0	10.0	6.1	5.6	15.0	9.3	13.4	6.9	17.0	18.0	12.8	21.1	18.6	5.4	18.8	14.5	8.3	21.4	20.8	19.2
111	7.8	11.7	11.7	8.3	9.4	9.5	13.9	4.4	12.4	16.4	19.4	22.4	21.0	-0.2	17.5	17.6	15.6	17.6	21.7	19.1
112	2.8	12.8	15.6	13.3	8.9	17.1	11.4	6.7	17.5	17.0	21.4	16.5	14.8	6.6	9.0	12.5	15.9	9.9	18.0	22.3
113	3.9	10.0	13.3	15.6	15.0	23.1	11.9	11.3	23.3	22.4	16.5	20.2	12.1	9.9	9.1	12.9	15.1	7.6	10.4	22.1
114	13.3	7.8	18.3	13.9	18.3	29.9	14.3	9.4	26.9	16.8	8.4	18.4	6.7	9.9	11.1	15.9	6.2	12.7	13.5	19.8
115	13.3	9.4	23.9	18.3	12.8	30.1	18.6	15.6	18.4	12.7	12.8	10.0	6.8	6.1	12.9	14.5	9.3	13.4	11.3	10.8
116	16.1	15.0	15.0	16.1	14.4	30.3	21.4	13.6	26.9	13.5	17.0	6.2	8.4	8.7	14.5	16.1	17.1	12.6	4.9	8.7
117	22.2	8.9	12.8	8.9	17.2	12.0	23.5	16.6	29.0	16.0	19.9	7.6	10.2	8.4	12.1	27.3	20.6	15.2	5.0	10.6
118	26.1	2.2	16.1	10.6	17.2	21.4	15.7	16.2	28.4	16.9	18.6	12.2	11.5	9.1	6.0	25.8	23.5	18.7	3.7	7.8
119	16.1	4.4	13.9	6.1	19.4	21.8	17.5	12.3	22.3	15.2	11.6	16.9	11.3	12.9	5.6	21.7	22.0	20.0	7.2	12.4
120	10.6	8.9	8.3	11.1	25.6	11.7	16.8	10.6	21.0	18.8	15.1	6.2	11.8	15.8	3.7	24.5	15.3	20.7	15.3	10.3
121	14.4	12.8	2.2	6.7	17.2	21.5	20.1	5.6	25.7	20.2	20.7	11.5	17.7	20.2	7.3	21.8	15.2	17.8	13.9	10.4
122	17.2	17.8	3.3	15.0	20.0	24.0	16.4	3.7	28.7	14.4	20.7	12.0	16.7	26.5	16.2	11.5	14.3	10.2	15.2	10.8
123	15.6	15.0	12.8	13.9	23.9	20.4	13.4	6.0	17.3	11.2	14.1	15.4	11.0	24.9	16.8	18.2	13.8	19.0	17.2	9.9
124	10.6	9.4	16.7	9.4	18.3	18.6	13.9	4.2	20.5	14.4	6.3	16.7	11.0	15.4	10.0	20.7	14.0	14.1	22.7	14.3
125	9.4	13.3	20.0	7.2	13.3	11.1	15.2	3.9	17.4	14.6	7.6	15.0	13.4	14.0	13.9	18.5	15.4	24.8	25.5	14.9
126	12.2	18.9	15.6	10.0	20.6	9.9	16.4	7.8	16.7	10.6	10.4	18.9	8.7	17.4	12.1	22.4	14.6	22.0	18.9	13.6
127	14.4	15.0	18.9	13.9	22.8	20.6	17.1	10.0	15.6	18.4	7.2	19.1	12.0	21.1	18.9	29.9	19.1	22.2	7.1	17.4
128	16.1	10.6	16.7	18.3	21.1	24.7	21.3	12.9	20.7	13.0	10.3	13.4	15.8	19.3	16.4	21.2	24.6	24.8	10.6	18.0
129	17.8	14.4	11.1	18.9	22.2	26.4	14.4	15.6	18.6	10.3	11.9	10.0	9.4	19.2	14.4	19.9	20.3	27.4	14.6	16.0
130	17.8	15.0	10.6	20.6	28.3	23.6	9.9	15.1	20.7	15.0	16.8	12.9	10.1	17.0	12.8	15.4	24.6	26.8	9.4	21.0
131	22.2	16.1	11.1	21.7	17.8	20.5	8.4	15.5	20.1	18.0	21.8	17.1	12.4	12.1	12.7	23.5	25.2	17.7	10.9	24.7
132	21.1	20.6	10.6	17.8	21.1	20.0	18.4	16.3	19.2	20.1	19.4	18.9	14.5	15.4	16.4	16.5	21.2	16.8	13.4	22.3
133	25.0	25.0	13.3	15.0	15.0	20.6	17.3	17.3	21.2	19.7	18.8	11.2	20.0	20.9	18.1	14.8	29.5	17.4	13.8	13.1
134	17.8	28.3	15.0	20.6	16.1	18.3	21.6	17.7	22.6	16.7	22.7	10.9	19.3	14.7	8.2	25.5	15.3	20.5	13.4	14.5
135	13.9	21.7	12.2	17.8	20.0	13.1	16.4	17.8	23.6	15.1	24.9	11.5	13.6	20.9	10.4	17.3	18.5	23.0	14.2	17.8
136	15.6	28.3	11.1	16.7	22.8	4.2	12.9	10.0	26.0	14.6	19.0	16.5	10.8	24.4	15.3	16.5	26.6	22.0	15.2	20.8
137	14.4	24.4	9.4	16.7	18.9	6.8	19.8	15.7	28.7	18.4	22.9	18.1	14.1	27.6	19.9	20.7	19.2	16.2	18.4	23.3
138	10.0	19.4	11.1	15.6	12.8	10.3	20.1	14.6	25.4	23.5	17.7	16.2	18.3	20.4	22.1	14.2	17.2	15.4	17.0	21.8
139	20.6	23.3	11.1	13.3	14.4	16.4	25.1	13.9	23.7	23.3	16.2	16.8	19.3	24.5	24.4	4.6	19.6	7.4	17.3	21.2
140	25.6	11.7	16.1	15.0	16.7	18.6	26.9	17.5	25.1	26.2	20.0	16.4	16.5	26.2	28.6	10.3	18.4	7.0	19.5	25.5
141	24.4	18.3	17.8	18.9	17.2	21.9	26.8	14.9	16.7	24.7	23.0	18.4	9.4	27.8	17.5	13.0	24.4	9.0	18.2	16.7
142	19.4	23.3	18.3	18.3	24.4	16.4	20.6	22.4	22.1	22.9	25.3	18.6	14.5	29.0	10.1	17.3	30.4	7.3	20.4	14.5
143	18.3	23.9	19.4	14.4	25.0	20.6	15.2	27.4	16.1	18.1	17.5	10.9	11.6	20.3	17.9	20.2	27.1	9.2	24.9	13.2
144	16.1	25.6	19.4	11.7	17.2	22.3	11.3	24.2	10.2	25.1	27.8	24.0	11.0	15.0	23.8	21.3	18.9	11.9	24.2	11.2

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
145	13.9	21.1	23.3	13.3	18.9	20.0	7.9	24.0	8.8	27.0	17.8	26.3	13.5	10.9	28.9	24.2	24.6	15.2	24.4	10.2
146	18.3	16.1	18.9	15.0	22.2	21.3	15.6	27.1	11.2	19.2	14.8	18.9	15.5	16.9	32.1	23.4	22.7	17.4	22.9	18.3
147	22.8	15.6	13.3	17.2	29.4	15.8	21.8	18.4	8.3	23.1	12.6	23.9	15.0	20.3	27.2	23.3	23.4	10.6	23.5	18.8
148	24.4	11.1	10.6	18.3	16.7	10.4	17.2	10.7	13.8	19.2	16.0	27.8	21.4	19.2	30.2	21.1	26.9	14.6	23.6	20.4
149	25.6	21.1	12.8	21.1	14.4	12.0	10.7	15.6	13.3	23.6	19.0	28.5	20.7	17.1	31.2	19.0	20.7	20.1	26.5	22.1
150	30.0	25.6	13.9	20.0	20.0	18.2	13.1	15.4	11.7	24.0	21.2	23.0	20.0	18.1	32.0	22.2	11.9	18.5	19.2	24.2
151	28.9	12.8	18.3	20.6	15.7	22.5	19.2	22.3	20.7	15.6	23.6	20.9	14.0	13.0	24.7	18.1	16.8	23.0	21.6	24.1
152	21.7	16.1	20.6	22.8	19.4	29.0	24.2	22.9	20.4	22.0	21.0	17.2	16.7	17.2	29.5	17.5	19.5	22.4	15.6	18.7
153	20.6	18.3	20.6	26.1	18.3	15.4	28.4	24.3	20.0	24.7	24.6	12.9	19.8	18.2	23.8	16.7	19.8	21.4	10.2	16.5
154	25.0	17.8	17.8	20.0	19.4	19.8	29.8	22.8	15.7	19.2	23.9	14.3	21.4	15.0	20.0	21.4	25.8	21.2	15.7	13.4
155	21.7	21.1	13.9	20.0	13.3	22.0	32.8	20.1	14.5	19.7	24.9	17.3	21.3	23.4	18.1	23.6	23.5	25.9	15.3	19.2
156	26.7	22.2	18.9	21.1	18.3	24.6	28.1	17.9	13.9	21.8	13.2	19.4	21.0	21.6	21.5	26.0	20.1	29.7	19.9	20.1
157	25.6	22.2	18.9	16.7	19.4	28.0	18.4	12.2	12.5	17.9	10.3	24.8	13.6	21.3	24.7	21.5	20.5	19.3	17.0	22.5
158	25.0	21.1	15.0	16.7	19.4	32.8	25.0	17.6	18.0	18.4	17.3	21.6	13.2	20.4	24.6	19.2	16.2	19.2	22.1	20.1
159	24.4	21.7	17.8	19.4	25.0	26.4	25.2	17.0	24.7	20.2	19.4	26.3	16.1	15.0	22.6	27.2	19.2	22.9	21.1	19.3
160	17.2	17.2	18.3	21.1	25.0	20.4	16.7	21.7	28.6	18.7	20.9	23.5	14.5	16.0	23.6	27.1	22.3	15.6	23.0	22.4
161	18.3	13.3	20.0	24.4	22.8	14.7	18.4	22.4	27.2	19.5	21.1	26.2	20.2	15.4	27.3	19.9	25.5	19.5	19.5	25.7
162	23.9	17.8	22.8	22.8	21.1	18.6	17.4	25.6	25.5	16.8	26.5	21.0	24.4	21.9	15.4	24.9	12.7	23.1	15.5	18.7
163	17.8	23.9	24.4	18.3	18.9	22.4	21.6	24.8	25.0	19.4	29.5	18.1	23.0	22.3	18.9	27.8	16.9	24.3	16.5	19.3
164	13.3	23.3	20.6	16.7	15.6	22.5	21.9	17.6	25.9	20.5	30.5	23.8	25.8	17.1	17.4	22.7	20.4	25.2	16.7	13.4
165	16.7	16.7	23.9	20.6	22.8	18.4	14.2	13.7	25.0	23.6	27.5	25.0	28.5	23.4	19.7	22.5	20.4	22.6	19.4	14.2
166	23.3	12.8	28.3	16.7	19.4	20.0	21.0	16.9	26.8	21.2	25.6	28.3	22.9	15.4	15.9	22.2	26.3	20.9	24.3	18.6
167	28.3	13.9	28.9	18.9	18.3	24.6	18.4	18.9	29.5	15.4	25.0	27.8	19.8	18.6	17.6	16.8	26.9	18.0	17.9	18.8
168	16.7	21.1	25.6	16.7	23.3	24.8	26.1	22.1	18.4	14.4	25.2	26.9	17.0	20.2	26.2	22.8	25.9	21.4	21.7	16.5
169	16.1	21.1	26.1	18.9	27.8	25.9	16.8	23.5	19.6	19.3	28.8	20.0	15.6	27.0	23.0	26.7	23.8	21.8	22.2	16.4
170	21.1	22.8	26.1	22.2	26.7	28.5	20.4	21.5	22.0	17.4	29.2	11.7	13.4	26.2	19.6	28.0	21.8	16.3	22.3	18.9
171	24.4	22.8	26.1	17.8	18.3	29.2	24.8	19.2	26.1	19.3	31.1	17.0	21.2	20.6	21.3	25.2	19.9	14.0	22.5	20.4
172	24.4	26.1	27.8	26.7	20.6	25.6	24.4	17.5	23.7	18.4	32.2	17.5	21.9	20.0	23.7	22.4	22.8	21.5	24.5	17.1
173	16.7	31.7	30.0	21.7	13.9	22.5	21.4	20.9	22.4	21.3	23.0	17.4	23.8	18.6	25.0	19.5	25.7	21.6	28.4	19.5
174	22.2	29.4	31.1	26.1	10.6	23.7	19.0	20.6	18.7	19.5	22.4	17.3	26.7	18.1	27.2	17.2	23.8	20.9	30.2	19.0
175	17.2	23.3	21.1	27.8	13.3	28.8	24.8	16.2	19.0	21.6	17.7	20.8	27.9	11.3	21.2	20.9	20.5	16.6	23.8	20.0
176	15.6	18.9	21.7	21.1	14.4	19.5	23.9	22.6	20.4	26.7	22.4	15.3	20.0	17.6	17.1	24.5	28.7	17.5	26.4	20.9
177	20.6	22.8	17.8	16.1	11.7	20.1	24.6	25.9	21.6	22.4	24.7	17.2	24.6	20.7	18.4	27.9	23.0	20.2	25.7	26.6
178	21.7	25.6	18.9	11.1	18.9	23.0	26.5	27.5	15.4	19.5	20.0	19.7	23.9	26.5	22.8	19.7	25.1	18.5	23.1	23.6
179	25.0	21.7	18.9	12.8	21.7	22.7	31.0	28.7	15.4	21.1	21.2	23.6	26.0	26.5	23.7	23.4	21.8	18.8	22.2	23.0
180	20.0	20.6	22.2	20.0	25.0	18.2	29.0	31.4	17.4	26.7	22.3	25.2	30.5	21.3	19.2	25.8	18.9	21.9	24.2	19.2
181	16.7	14.4	20.0	23.3	25.6	20.9	26.4	28.9	19.8	25.2	20.3	20.2	20.2	23.9	21.1	20.5	23.1	24.2	25.4	21.8
182	13.3	16.7	17.8	25.6	22.2	23.4	24.3	19.5	25.1	23.0	28.3	20.3	21.0	25.3	24.9	24.9	21.9	19.5	20.5	23.7
183	17.2	22.8	20.6	29.4	22.2	18.9	26.9	18.8	27.7	27.3	20.1	18.3	20.6	27.7	25.3	30.1	20.5	19.7	15.5	26.5
184	20.0	23.9	21.1	31.1	24.4	20.6	28.0	21.2	26.1	31.4	16.6	26.4	23.7	27.8	19.5	23.3	19.8	23.7	13.0	25.3
185	21.1	23.9	20.6	30.6	26.7	21.1	29.9	25.6	22.5	26.0	15.6	24.0	23.6	32.6	17.1	16.5	20.3	20.7	17.5	23.4
186	21.1	19.4	17.8	30.6	25.0	15.0	23.9	27.0	19.3	25.0	18.8	25.9	25.7	27.7	17.2	15.9	16.3	20.0	21.8	21.8
187	16.1	19.4	19.4	31.1	26.7	14.6	16.9	29.9	16.7	24.5	22.8	22.8	16.7	29.0	20.8	19.1	13.0	25.2	16.3	16.5
188	19.4	20.0	18.9	23.3	27.8	20.0	15.2	26.2	24.7	12.9	23.3	20.9	17.9	27.3	23.2	23.4	20.5	25.4	21.6	21.7
189	18.3	22.2	21.1	25.6	26.1	21.6	21.8	26.5	29.0	20.7	19.4	20.6	20.9	28.0	25.8	18.5	23.5	13.5	25.4	23.6
190	19.4	23.3	21.7	27.8	25.6	23.2	23.7	28.0	29.1	21.0	24.6	22.4	22.9	30.3	18.5	17.4	21.4	20.2	24.5	25.9
191	15.6	28.3	23.3	30.0	23.3	18.0	22.4	21.6	24.5	23.0	26.8	24.0	27.4	30.7	22.4	18.2	21.7	18.0	26.0	22.9
192	19.4	22.8	19.4	32.2	23.3	22.6	15.6	17.3	22.5	24.8	25.7	25.1	26.3	25.4	18.0	21.2	26.0	18.7	27.6	25.4

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
193	23.3	20.6	14.4	32.2	22.2	15.8	25.4	15.5	21.3	27.9	26.5	20.6	24.7	18.9	14.7	22.7	19.5	23.5	30.8	27.6
194	21.7	22.2	21.7	25.6	22.2	20.1	23.2	14.0	26.5	26.6	26.0	24.6	21.5	19.0	14.1	26.9	21.5	25.1	25.2	30.8
195	21.1	26.7	25.6	25.6	16.1	17.1	25.9	19.9	24.1	17.5	21.0	20.4	22.4	24.5	20.6	27.5	16.9	26.7	22.3	24.0
196	22.8	22.2	29.4	22.2	25.0	18.4	28.4	24.7	23.7	19.8	17.4	13.4	25.3	23.0	18.5	21.1	20.1	27.4	23.0	26.1
197	21.1	20.6	23.3	21.7	30.6	24.1	25.3	27.2	21.2	21.4	21.0	16.2	26.6	24.0	17.5	14.5	21.3	24.0	19.5	24.0
198	18.9	18.9	25.0	19.4	25.0	21.9	18.1	31.2	16.4	25.1	24.5	19.4	26.4	21.3	15.9	18.4	21.1	21.0	17.5	22.7
199	15.6	21.7	27.8	15.6	22.2	17.6	17.0	33.0	17.8	28.6	23.6	24.6	25.0	26.0	19.7	19.9	21.7	25.1	18.3	21.8
200	20.0	25.0	27.8	23.3	23.9	15.4	21.2	33.3	15.2	29.0	20.2	27.2	22.4	17.2	21.0	15.2	24.4	28.5	16.8	22.2
201	21.1	31.7	21.1	22.2	27.8	24.4	23.4	29.2	24.1	23.7	16.4	25.2	17.1	25.3	26.3	23.2	28.1	28.6	19.5	20.5
202	20.0	23.9	25.0	21.1	25.0	30.1	24.3	25.9	26.9	22.6	20.9	22.3	17.4	29.3	27.0	20.3	30.8	23.7	22.4	21.2
203	17.2	16.7	25.6	21.1	24.4	25.9	27.0	22.6	30.5	17.9	17.1	24.2	25.3	23.5	26.6	20.7	22.2	22.1	25.1	24.0
204	18.3	22.8	23.9	25.0	28.9	23.2	28.9	20.4	24.9	22.0	23.4	27.6	27.3	20.4	17.2	25.3	22.5	23.7	25.4	26.3
205	21.7	21.1	26.1	30.0	25.0	24.2	26.0	19.4	19.7	19.0	24.0	25.1	29.5	21.1	22.4	27.8	25.6	20.5	22.7	28.4
206	18.3	23.3	20.0	23.3	26.7	28.6	27.0	21.5	22.4	21.1	24.3	25.2	30.7	25.4	20.9	29.8	26.3	23.1	25.3	30.3
207	21.1	23.3	22.2	26.1	21.1	29.2	31.3	24.9	23.1	25.7	25.9	21.3	33.4	20.4	20.1	26.4	31.0	26.8	21.5	23.8
208	25.6	19.4	20.0	30.0	15.0	28.6	24.4	27.6	23.8	28.0	26.7	21.2	29.6	23.4	18.0	31.7	21.3	26.8	25.4	25.3
209	25.0	21.7	24.4	21.1	19.4	22.4	21.4	28.4	20.3	22.9	25.5	24.6	28.8	23.0	19.7	31.3	22.4	25.7	21.9	25.2
210	20.6	25.6	25.0	20.0	19.4	15.6	22.4	17.0	22.6	16.3	29.0	24.4	28.8	24.0	17.4	29.0	25.2	25.9	24.3	20.4
211	20.0	27.8	25.6	20.0	21.1	21.1	22.9	23.5	21.6	19.0	30.6	25.6	28.6	26.4	19.8	30.1	21.7	24.1	28.0	21.7
212	21.1	29.4	20.0	22.2	20.6	21.7	25.0	27.9	26.9	22.9	25.7	30.6	30.1	26.3	22.2	25.2	21.6	28.1	28.0	24.6
213	17.8	25.6	20.6	24.4	23.9	23.2	14.4	24.8	27.6	23.6	24.6	29.3	30.3	29.4	25.7	13.4	18.1	28.9	25.0	22.9
214	22.2	25.6	25.6	19.4	30.0	23.6	19.6	22.5	19.5	25.7	19.1	31.4	30.8	31.4	27.2	15.8	22.4	23.9	20.5	24.5
215	23.9	22.8	29.4	18.9	23.3	20.6	27.3	14.8	12.2	25.7	14.9	28.1	26.2	29.9	28.0	17.6	25.6	21.4	23.6	28.2
216	17.8	27.8	30.0	23.3	22.2	18.8	30.5	18.3	17.5	25.7	22.8	24.4	28.6	28.0	22.5	22.4	26.2	20.7	26.9	30.1
217	23.3	18.3	25.0	25.6	25.0	24.5	23.6	22.0	15.4	27.6	24.4	29.6	29.5	24.5	18.0	21.4	17.8	16.6	30.2	29.0
218	26.1	12.8	18.9	20.6	26.1	16.6	27.6	23.3	18.0	27.6	23.5	26.0	25.9	22.5	24.0	24.1	13.2	21.7	33.2	23.3
219	25.6	22.2	20.6	24.4	25.6	24.4	24.9	22.8	17.6	28.7	23.4	25.0	24.0	22.4	25.9	25.4	19.5	27.9	25.7	28.6
220	30.0	25.0	20.6	18.9	22.8	20.1	27.4	17.9	21.6	30.2	24.4	29.0	26.4	13.1	20.5	20.8	23.7	26.1	24.7	31.7
221	25.6	28.3	23.3	21.7	23.3	17.3	32.3	20.1	25.1	29.5	25.2	29.6	32.4	15.4	19.9	16.5	20.9	29.6	26.8	33.9
222	22.2	23.3	20.0	20.0	24.4	23.1	31.4	26.4	19.0	33.2	27.7	33.5	27.3	17.9	24.7	14.4	21.5	23.8	28.3	25.9
223	19.4	21.7	17.8	18.3	27.8	18.0	22.6	22.6	19.8	29.0	19.0	26.7	25.8	18.2	28.4	14.4	21.5	25.1	27.0	23.3
224	17.8	27.2	14.4	21.7	25.0	17.8	19.4	20.5	21.9	24.7	19.0	24.1	29.7	16.4	26.9	14.6	24.8	28.2	29.8	23.3
225	18.3	28.9	15.0	15.6	27.2	17.2	19.3	18.2	24.0	22.8	21.2	26.6	20.2	19.4	25.4	15.1	26.9	28.3	22.9	23.7
226	23.3	26.1	17.8	22.2	28.9	20.7	21.4	22.2	26.2	27.8	17.2	21.8	19.8	18.3	21.4	16.1	21.8	27.8	23.8	26.6
227	26.1	20.6	20.6	16.1	27.8	20.3	19.5	22.6	21.7	31.2	15.0	24.5	24.0	19.1	18.8	19.0	19.6	22.0	24.2	26.6
228	26.1	21.7	23.3	17.8	25.6	21.0	14.2	25.7	22.4	30.1	21.4	21.6	27.8	20.0	20.0	19.1	18.7	20.5	18.4	26.3
229	27.8	17.2	20.6	12.8	16.1	27.4	13.2	27.3	18.9	28.0	24.9	22.5	32.7	22.8	26.2	16.0	18.8	19.7	17.2	29.1
230	23.9	11.1	23.3	13.3	23.3	26.4	16.1	26.7	19.0	27.7	23.3	16.4	24.5	25.3	28.9	19.1	19.9	20.5	18.2	31.1
231	26.1	16.1	11.1	15.6	22.2	24.0	9.7	22.7	23.1	32.2	23.2	22.7	19.3	21.4	17.3	18.5	21.9	18.6	24.6	26.0
232	21.7	20.0	16.1	21.7	20.6	23.6	11.9	26.2	17.6	26.4	23.0	20.1	15.9	13.2	22.4	16.1	14.8	23.1	27.8	23.2
233	25.6	22.2	17.2	22.2	21.7	15.6	17.1	22.6	18.8	25.3	24.0	21.3	23.1	12.5	19.4	17.8	20.5	21.4	27.4	22.5
234	25.0	23.9	19.4	15.0	23.9	13.4	22.8	23.5	21.7	28.1	20.0	26.0	29.3	22.3	23.7	20.4	21.4	21.3	21.5	22.5
235	25.0	19.4	16.7	15.0	20.6	12.8	16.3	25.5	17.1	28.1	21.0	27.3	22.6	27.0	27.2	20.6	25.4	18.4	14.4	22.4
236	27.2	16.7	20.0	15.0	25.0	13.4	16.5	19.2	11.8	29.5	19.6	24.6	24.5	28.0	17.6	20.0	22.4	19.8	12.3	19.4
237	27.8	20.6	15.6	15.6	19.4	19.4	20.5	18.6	15.2	29.6	11.0	22.6	23.1	21.0	16.5	15.3	24.4	17.5	14.6	20.5
238	26.7	22.8	18.9	17.2	14.4	14.9	21.3	21.6	20.5	32.0	12.2	25.4	26.3	17.4	22.7	20.1	16.8	19.1	13.5	21.7
239	25.0	18.9	18.3	25.0	18.3	19.2	21.0	26.2	19.6	28.9	14.6	24.7	21.3	20.1	26.6	24.0	20.9	15.9	21.4	22.3
240	27.2	20.6	20.0	22.2	21.1	21.0	22.6	22.1	14.0	25.0	15.6	24.9	16.3	20.4	29.3	15.8	25.7	13.6	23.9	21.8

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
241	22.2	19.4	21.7	17.8	22.8	14.3	23.6	19.4	18.8	18.0	11.2	26.4	16.1	21.7	23.2	15.0	28.3	10.8	25.2	20.5
242	15.6	13.3	16.1	15.6	23.9	13.2	25.1	22.3	18.3	10.9	11.1	24.2	16.6	16.2	21.9	21.4	18.5	12.3	19.9	29.2
243	17.8	13.9	16.1	13.9	23.3	9.1	25.6	23.3	15.7	19.4	17.6	27.1	19.3	18.4	21.0	22.6	20.6	13.1	11.9	25.5
244	20.6	16.7	17.2	17.2	25.0	14.3	22.3	23.0	17.9	21.3	19.6	23.7	15.3	18.1	20.7	23.1	25.5	19.7	20.7	18.5
245	21.7	21.1	22.2	17.2	17.2	15.9	26.8	23.8	12.8	11.4	26.5	19.5	13.4	17.9	20.0	18.9	29.3	13.9	19.1	16.9
246	16.1	20.6	25.0	15.0	18.9	14.0	21.1	21.4	16.4	17.0	25.6	20.6	12.7	15.7	18.2	18.2	29.1	20.1	18.4	18.4
247	17.2	19.4	18.3	17.8	24.4	12.6	17.3	19.7	20.4	15.2	14.3	18.6	23.1	18.9	12.8	20.3	28.6	21.0	22.9	13.8
248	13.3	25.6	8.9	17.2	18.9	16.0	14.7	16.4	24.7	20.0	14.6	10.5	24.4	12.0	14.2	22.5	30.3	14.8	22.3	22.3
249	6.1	26.1	11.7	19.4	11.1	19.2	15.5	18.9	28.7	22.7	22.2	17.0	15.7	5.9	17.1	16.7	22.0	17.2	22.4	24.2
250	9.4	17.8	6.7	23.3	10.6	17.9	16.6	17.7	16.1	28.6	25.7	16.6	8.6	6.9	18.7	18.1	14.9	15.9	24.9	18.6
251	17.2	20.0	6.7	17.2	17.2	17.9	14.9	19.4	18.3	30.3	21.8	12.0	10.7	9.9	19.8	20.4	16.1	12.7	15.0	11.0
252	15.0	17.8	7.2	18.3	23.9	16.6	19.3	13.8	25.4	32.9	22.2	9.7	10.4	13.0	20.2	20.4	13.2	9.3	21.1	16.5
253	17.2	22.8	4.4	13.3	17.2	18.1	19.6	15.0	24.7	22.3	15.6	15.3	10.7	15.7	17.5	22.2	11.6	10.1	25.5	19.4
254	14.4	25.6	8.3	16.7	12.8	19.2	12.1	11.0	17.4	24.0	14.3	14.6	11.8	15.2	8.8	23.9	16.8	16.3	23.2	19.6
255	16.1	12.2	17.2	23.3	10.0	21.5	9.6	17.9	9.9	18.8	9.0	15.1	8.1	15.6	6.4	25.4	22.2	23.2	16.1	22.1
256	22.8	4.4	24.4	25.6	18.3	21.4	11.4	22.4	9.0	15.4	10.8	16.0	13.0	14.5	9.6	16.4	24.5	23.5	21.8	16.9
257	17.8	8.3	23.9	23.3	23.9	10.6	17.1	27.1	12.4	20.2	14.6	18.0	16.2	18.3	8.6	16.1	25.4	23.5	22.1	13.1
258	18.3	12.8	23.9	20.0	22.8	10.5	14.8	30.1	10.6	24.5	19.5	14.5	20.1	19.0	8.8	15.1	19.3	16.5	25.2	16.2
259	12.8	15.6	25.0	16.1	24.4	11.0	8.4	20.4	9.8	29.9	19.9	9.5	23.6	17.4	9.2	15.8	12.6	11.3	21.6	12.6
260	12.2	16.7	20.6	11.1	18.9	9.4	7.0	20.7	8.3	33.6	24.4	7.0	19.3	8.0	9.9	16.3	7.3	8.2	15.9	9.6
261	10.0	17.8	17.8	11.7	19.4	15.6	9.1	23.6	8.0	30.6	22.3	5.2	17.7	4.6	13.6	19.8	11.3	13.3	21.2	16.0
262	7.8	17.2	17.8	16.7	21.1	19.4	13.4	17.6	12.7	21.8	22.1	10.0	16.9	6.5	14.6	21.1	9.7	17.5	17.1	25.0
263	6.7	11.7	17.8	21.1	23.3	18.7	18.3	20.6	13.6	14.8	24.0	11.4	12.0	16.2	12.1	22.4	7.7	18.8	16.5	15.0
264	1.7	8.3	21.1	25.0	23.3	14.8	15.3	17.6	7.5	18.0	22.0	14.6	7.1	12.0	15.9	26.6	13.8	14.6	16.2	11.8
265	3.9	10.6	23.9	25.0	20.0	16.2	15.3	18.3	10.9	12.2	21.7	22.4	2.3	6.2	19.0	27.8	13.9	17.0	25.1	11.4
266	-0.6	10.6	20.6	25.6	23.3	18.5	15.3	19.2	13.6	11.7	23.6	20.0	3.0	7.3	17.2	18.9	11.6	21.9	28.1	16.6
267	-1.7	11.1	22.8	24.4	21.1	14.6	16.0	22.2	7.2	11.6	23.5	17.1	4.9	11.7	19.1	18.8	10.0	16.6	28.4	22.8
268	1.1	11.7	24.4	15.0	18.9	12.1	11.9	24.8	15.7	10.5	17.9	23.6	4.9	17.7	14.5	22.4	6.1	22.1	21.6	22.9
269	1.1	17.8	15.6	15.0	20.6	9.3	15.9	18.6	15.3	12.4	10.2	24.1	5.4	12.9	7.3	14.9	8.7	25.0	16.0	21.8
270	4.4	22.8	7.2	17.8	24.4	11.6	15.6	17.6	18.4	10.0	9.5	11.5	9.2	3.5	7.1	16.5	7.2	20.7	14.4	22.9
271	6.7	18.9	7.2	15.6	24.4	14.6	17.8	15.1	19.6	12.6	6.2	7.2	12.8	7.6	8.5	19.5	15.0	21.7	15.6	21.8
272	16.7	15.6	5.0	13.9	22.8	13.0	21.1	16.4	23.2	13.6	8.4	10.9	16.3	11.9	13.6	20.3	24.5	25.1	15.0	13.3
273	20.0	8.9	0.0	18.3	16.7	13.8	18.3	16.2	17.6	16.8	15.6	11.7	19.1	18.5	8.2	24.7	16.3	13.7	16.3	16.1
274	17.2	3.9	12.2	25.6	13.9	10.4	13.0	16.0	16.2	17.9	16.1	15.8	18.4	16.6	4.1	18.2	13.0	4.0	15.3	12.8
275	18.3	11.1	15.6	25.6	10.6	11.4	15.1	15.7	23.7	10.9	11.5	11.5	16.7	15.3	4.7	28.6	13.3	10.8	11.2	11.7
276	12.8	15.0	8.9	26.7	7.2	2.9	13.7	20.6	24.9	11.8	7.7	16.4	20.0	10.3	14.4	18.8	14.1	18.2	8.0	9.2
277	8.3	9.4	1.1	14.4	6.1	4.8	11.8	18.6	26.4	11.5	10.6	10.2	23.7	11.9	10.6	12.4	17.9	18.8	1.9	9.2
278	12.2	11.1	3.9	14.4	10.6	5.2	13.7	17.6	25.1	13.5	12.3	11.0	18.3	11.9	20.9	16.6	21.0	9.4	-0.4	18.2
279	22.2	3.9	15.6	10.0	13.9	8.0	18.9	15.7	28.0	15.7	12.6	10.9	18.8	3.3	21.2	12.5	21.7	14.1	3.9	23.1
280	17.2	5.0	17.2	3.3	23.9	11.4	20.0	10.7	22.7	17.0	14.7	15.2	24.4	2.7	7.0	11.9	20.1	19.8	6.3	15.2
281	15.0	10.0	24.4	7.2	21.1	10.1	20.4	11.0	17.6	8.2	12.9	14.9	27.1	1.5	9.6	4.3	20.2	17.2	9.6	13.1
282	9.4	7.2	25.0	10.0	20.6	2.2	22.0	19.8	14.4	4.9	15.1	13.7	22.5	6.4	12.1	6.1	19.3	16.8	14.3	23.7
283	-5.6	11.1	13.9	7.8	17.2	9.0	16.0	24.6	14.7	8.1	22.7	7.2	23.0	16.0	7.5	14.6	22.4	12.7	6.2	21.6
284	6.7	13.9	12.2	8.3	17.2	18.7	12.4	17.6	14.6	6.6	18.2	15.6	17.0	12.3	15.0	23.7	19.0	12.6	3.3	24.1
285	16.1	10.6	17.8	12.2	14.4	19.0	11.4	19.5	12.2	5.6	18.1	18.1	14.7	10.5	19.4	18.5	24.6	9.5	11.1	17.0
286	8.3	13.3	9.4	14.4	12.8	12.4	12.5	22.7	5.6	9.9	25.5	15.0	11.0	6.7	16.2	11.3	21.6	9.7	10.6	9.2
287	15.0	10.0	13.3	14.4	4.4	12.8	16.7	17.0	5.2	18.1	17.3	10.4	8.3	4.6	20.4	10.8	16.2	6.2	7.9	16.9
288	15.6	11.1	20.6	10.0	6.7	22.3	16.6	10.4	8.5	18.0	16.3	3.4	5.5	4.0	22.2	10.8	12.1	4.5	6.5	16.7

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
289	6.7	8.3	15.0	12.8	5.0	13.6	14.2	11.4	9.6	14.3	10.4	3.6	0.3	8.6	19.9	13.4	10.8	5.2	5.9	3.1
290	1.1	11.1	11.1	17.8	7.8	17.4	12.8	9.1	17.7	12.2	5.1	6.9	0.9	13.7	17.2	9.0	9.5	10.1	7.5	-4.0
291	12.2	11.7	20.6	10.6	12.2	17.6	23.9	9.7	18.2	19.0	-0.6	11.0	1.0	13.0	14.8	8.0	9.3	17.4	13.8	2.5
292	18.3	12.8	21.1	13.3	10.6	11.5	22.7	7.0	15.5	11.5	1.6	14.6	1.6	16.4	13.8	3.9	16.1	14.5	5.5	6.0
293	9.4	9.4	17.8	10.6	7.2	8.2	10.6	3.7	8.5	2.6	6.2	15.5	1.4	11.1	19.3	9.2	11.2	19.8	6.4	12.0
294	2.8	6.1	8.9	8.3	8.3	11.0	9.3	5.1	7.5	1.1	9.1	15.5	-0.6	17.2	17.5	6.1	18.8	18.2	9.9	5.7
295	6.1	4.4	18.3	5.6	0.6	20.0	6.6	4.4	6.3	1.6	15.3	12.0	2.4	14.3	17.7	9.4	8.4	14.8	8.5	-5.5
296	8.9	3.9	16.7	3.9	2.8	21.3	15.6	6.9	8.4	8.8	15.8	9.0	3.7	11.4	16.8	6.8	12.2	10.3	9.6	-6.2
297	15.0	3.9	16.1	2.8	0.6	11.6	9.2	12.3	3.9	3.6	16.4	8.2	0.7	11.9	15.6	15.8	10.3	6.7	18.4	-1.3
298	14.4	4.4	16.1	4.4	0.0	12.6	8.8	8.6	3.3	8.3	14.5	14.1	6.1	7.2	16.6	11.3	6.1	13.7	14.8	-3.7
299	-0.6	6.7	16.7	-1.7	14.4	13.4	10.6	16.5	0.2	6.4	15.9	12.7	1.0	4.6	15.5	8.6	2.4	11.4	5.5	-7.1
300	-1.1	14.4	12.8	-3.3	15.6	12.3	10.1	12.1	2.3	4.3	10.9	6.4	-9.0	7.4	10.8	12.2	-4.4	2.3	8.9	-13.7
301	-2.2	10.0	12.8	0.0	11.1	15.3	6.8	9.2	12.1	12.9	13.4	8.7	-12.4	3.3	2.0	19.5	-0.7	2.1	10.8	-9.5
302	-2.2	9.4	7.2	-3.3	7.8	14.2	4.7	9.3	12.0	8.9	5.1	13.0	-12.7	5.1	1.6	13.9	4.1	7.6	8.7	-8.2
303	6.1	7.2	4.4	-0.6	7.2	11.5	9.8	10.1	9.0	10.4	8.5	14.6	-13.4	6.6	1.5	12.8	14.9	4.7	11.3	-6.8
304	12.2	2.2	4.4	7.8	13.3	9.7	11.8	8.7	6.6	19.9	9.5	10.8	-17.7	5.9	-1.6	10.1	9.8	-3.5	5.2	-8.3
305	5.6	-1.1	3.9	6.7	8.3	5.3	19.1	7.1	8.5	10.9	5.6	5.7	-15.1	6.1	3.8	9.6	8.9	0.1	3.5	-12.0
306	5.0	-5.0	10.6	7.8	11.1	5.7	14.8	4.1	13.3	7.7	2.1	7.0	-12.6	4.8	10.6	11.9	9.2	7.1	0.5	-10.4
307	3.3	-10.6	12.8	19.4	12.2	6.4	7.7	-0.9	11.3	6.2	2.8	8.4	-10.1	4.7	11.2	8.9	0.7	7.5	1.8	-0.6
308	0.6	-11.1	13.3	15.6	14.4	5.1	4.5	-0.7	14.7	8.0	5.5	12.2	-7.2	4.0	11.3	6.7	9.6	5.5	0.2	-1.6
309	-2.2	-13.3	12.8	13.3	7.2	4.4	4.1	1.4	16.2	16.8	8.8	8.7	3.4	4.6	7.5	7.1	8.4	8.0	-4.0	-9.2
310	-4.4	-12.8	7.2	5.6	6.1	7.9	9.8	-5.4	7.1	15.2	3.2	6.6	-1.6	-1.7	5.4	6.5	8.5	5.8	5.0	-2.8
311	-1.7	-14.4	5.6	5.6	9.4	5.7	12.5	-0.4	3.7	7.2	-2.2	1.0	-2.0	-8.1	-9.1	7.1	5.3	2.9	10.4	3.6
312	1.7	-13.3	7.2	5.0	10.0	3.8	2.6	-1.6	4.1	6.1	-2.9	-0.4	-0.2	-9.2	-15.6	8.3	1.5	5.1	3.2	0.8
313	-0.6	-10.6	6.7	2.8	10.0	5.7	-7.3	2.4	3.4	12.9	2.7	-1.9	-4.0	-11.6	-15.5	7.9	0.7	1.4	2.3	-2.8
314	-3.3	-10.6	7.8	-0.6	1.1	5.2	-6.7	3.6	2.3	13.5	2.6	-1.9	-4.0	-11.6	-11.2	13.4	-4.0	7.8	-1.8	6.3
315	-2.2	-8.3	3.9	2.8	1.1	9.6	-0.9	5.9	0.3	15.0	-6.2	1.9	-8.3	-12.1	-11.8	13.0	-4.0	-0.7	-8.9	7.4
316	-2.8	-6.1	2.8	8.9	5.0	9.8	-4.2	9.6	1.6	11.1	-5.0	7.4	-8.0	2.2	-11.7	9.0	-4.4	0.2	-5.5	7.8
317	-0.6	-5.0	1.7	15.6	6.1	11.1	-2.6	11.7	5.2	6.0	-3.4	-2.4	-12.8	4.8	-5.9	5.8	-3.9	-3.8	2.4	5.4
318	-0.6	-5.0	5.6	11.1	4.4	10.1	2.2	16.1	4.3	2.2	3.8	3.4	-12.1	8.1	-12.8	3.3	-2.7	-8.1	4.2	2.9
319	-2.8	-5.6	8.9	15.6	9.4	5.9	-1.0	17.7	4.7	1.8	4.8	3.4	-1.4	6.3	0.1	3.5	-3.7	-8.3	4.5	4.5
320	-4.4	-5.6	6.1	6.7	7.2	3.8	-2.3	8.3	4.7	1.7	-2.1	-1.0	-7.6	1.9	-3.6	-2.5	0.8	0.9	7.2	6.9
321	-1.7	-7.2	0.6	2.8	12.8	-1.0	-14.0	10.1	7.9	1.2	-1.2	-1.6	-4.6	-17.6	-15.7	-1.5	-6.3	3.9	2.9	6.8
322	-5.6	-15.6	-1.1	0.0	7.2	-7.1	-15.3	5.7	7.6	-0.2	-5.8	-0.1	-7.8	-15.0	-17.1	4.6	-2.8	8.3	1.9	1.3
323	-6.1	-12.2	-2.8	-1.1	5.0	-14.7	-14.4	4.4	5.6	-1.0	-15.4	0.3	-4.7	-15.7	-14.8	2.7	0.2	8.4	2.5	3.1
324	-5.0	-8.3	-6.1	0.0	2.2	-15.3	-10.6	8.7	7.1	4.4	-17.7	-0.6	2.2	-18.4	-10.7	7.6	-0.6	1.0	-2.3	1.0
325	0.6	-11.7	-4.4	-7.8	-2.2	-12.5	-8.1	7.4	5.4	3.2	-15.7	-2.1	-1.4	-17.4	-2.9	6.2	1.5	-1.4	-10.4	1.1
326	2.2	-12.2	-2.2	-10.6	2.2	-17.9	-7.3	10.7	2.1	4.2	-7.7	-4.8	5.6	-20.9	-7.1	-0.7	2.7	-4.2	-13.3	-0.7
327	6.1	-13.3	0.0	-12.8	6.1	-19.2	3.6	5.2	-0.4	-2.3	-5.8	-5.3	7.3	-13.4	5.5	-0.4	4.6	-5.9	-16.1	-5.6
328	3.9	-8.3	1.7	0.0	3.9	-14.3	3.1	2.7	3.5	-4.5	-5.5	-5.3	2.8	-21.3	5.6	0.4	0.9	1.5	-18.4	-1.3
329	6.7	-7.8	3.3	0.0	-3.3	-5.2	3.2	1.2	6.9	1.2	-15.4	-8.1	-5.4	-26.5	1.3	4.0	-5.8	-5.2	-17.7	2.5
330	2.8	-8.3	1.1	-4.4	-9.4	0.4	0.2	-1.1	4.7	-0.4	-10.5	-5.5	-3.6	-27.8	5.5	3.8	-14.7	-6.8	-9.4	-2.4
331	-0.6	-12.8	2.2	-5.6	-2.8	1.5	4.2	-6.8	6.4	-0.4	-2.0	-0.1	-1.7	-18.5	0.2	6.3	-7.2	-4.4	-3.5	-4.3
332	-0.6	-10.0	2.2	-11.1	-1.7	0.7	4.6	-7.6	5.9	3.7	-0.4	-1.0	-3.8	-15.4	-0.6	4.0	3.4	8.7	0.7	2.2
333	2.8	-12.8	0.6	-15.6	5.6	5.4	-11.0	-8.2	-0.4	6.0	-3.2	-10.0	-6.1	-16.3	-3.9	6.7	4.7	5.7	4.1	-11.2
334	0.6	-12.8	-3.9	-13.9	5.0	4.1	-11.3	0.4	-11.7	2.9	-9.2	-11.0	-8.4	-17.0	-1.4	3.5	10.4	5.2	-4.0	-4.3
335	-14.4	-12.8	1.1	-17.2	11.7	-1.0	-15.1	2.8	-19.9	6.7	-2.8	-10.4	-9.4	-17.9	-0.4	2.5	7.5	2.2	-18.1	-9.0
336	-16.7	-10.6	-0.6	-10.0	7.8	-6.0	-8.1	-2.9	-19.2	4.5	-3.7	-6.8	-11.0	-16.0	-4.3	5.6	3.5	-0.4	-19.3	-18.4

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
337	-18.9	-12.2	-2.8	-11.7	1.7	-10.2	5.0	-2.0	-18.7	1.4	-4.0	-4.1	-8.0	-12.5	-8.3	2.6	1.4	8.7	-4.6	-17.9
338	-15.6	-10.6	-1.7	-15.0	-5.0	-21.7	-0.3	2.0	-19.0	2.3	0.0	-6.0	-3.2	0.1	-5.0	5.8	8.9	6.7	7.5	-14.2
339	-17.8	-7.2	4.4	-11.7	-13.9	-26.0	-9.2	6.2	-21.2	2.8	-0.9	-3.3	-6.2	4.3	-4.6	2.8	7.0	0.9	1.6	-13.6
340	-21.1	2.8	3.3	-3.3	-13.9	-25.7	-7.6	8.9	-23.2	1.8	-5.8	-3.5	7.7	1.4	-2.3	4.4	-2.3	-5.4	7.5	-9.2
341	-22.2	-1.7	0.0	1.1	-12.8	-27.5	-8.2	-2.4	-10.1	1.7	-14.7	-9.8	6.4	-3.8	3.8	5.6	-8.8	-2.3	8.5	-10.0
342	-15.6	-1.7	7.8	6.1	-15.0	-28.7	-2.7	2.9	-7.8	-4.4	-0.9	-20.4	2.1	-4.4	-3.1	4.3	-6.9	-3.2	8.8	-5.5
343	-9.4	-0.6	6.1	6.1	-14.4	-29.8	3.6	2.8	-21.2	-3.7	1.7	-17.6	0.6	-7.0	0.5	2.4	-4.1	-7.2	1.9	2.2
344	-3.3	0.6	1.7	-5.6	6.1	-23.3	0.0	-8.3	-16.9	-3.8	-8.4	-16.9	-1.5	-5.0	4.2	4.7	3.7	-17.6	-1.6	2.8
345	-3.3	0.0	-2.2	-20.6	-13.9	-16.4	-3.5	-5.2	6.1	-3.7	-5.3	-11.6	-15.0	-0.4	1.6	1.8	4.4	1.0	-1.4	0.0
346	-15.6	-13.3	0.0	-17.2	-1.1	-4.0	-3.6	-5.4	1.2	-6.1	-3.6	-8.5	-10.4	-14.7	-2.4	-0.4	5.7	0.5	-6.4	-5.5
347	-13.3	-19.4	-5.6	-20.6	5.6	-3.2	1.0	-20.3	-1.0	-9.2	-4.2	-9.0	-4.4	3.5	1.6	-1.3	0.8	1.3	-4.2	-7.0
348	-11.7	-20.6	-5.0	-5.6	3.3	-2.6	4.2	-20.2	7.7	-12.0	-4.2	-18.9	0.4	2.2	-3.2	-1.3	-5.1	3.6	-0.1	-2.2
349	-7.2	-10.0	2.2	-5.6	6.1	-6.7	-0.5	-24.5	10.4	-8.0	0.7	-19.0	-21.0	0.4	0.1	-1.3	3.0	0.6	-5.0	6.3
350	-7.8	-5.0	3.9	-21.1	6.1	-4.7	-1.8	-13.4	8.3	-2.8	-1.0	-22.5	-23.1	1.4	2.4	-4.8	4.0	-5.8	-11.3	5.1
351	-13.3	-1.1	4.4	0.6	0.6	-5.3	-10.4	-10.0	-1.6	-3.0	-1.5	-20.0	-21.0	2.1	-0.2	-6.9	6.1	-12.2	-4.4	-2.7
352	-3.3	-4.4	-3.3	6.1	-1.7	-9.1	-13.0	6.1	-17.3	-2.0	-3.0	-20.2	-2.2	5.1	-0.3	0.6	3.2	-20.2	-19.1	-6.2
353	-3.9	-5.6	3.3	6.7	-8.3	-12.3	-3.0	7.6	-19.9	0.2	-7.7	-25.2	-2.1	5.9	-3.7	0.7	0.3	-22.3	-26.8	1.4
354	0.0	3.9	2.2	3.9	2.8	-7.6	-0.7	5.5	-19.8	5.2	-7.8	-23.0	0.7	6.9	-0.9	1.0	-3.6	28.1	-26.2	3.1
355	-3.9	3.3	0.6	-1.7	2.8	-4.2	2.1	0.0	-18.7	0.6	-8.9	-18.9	-20.6	8.3	2.2	2.2	-7.6	-23.2	-23.4	7.9
356	-11.1	-1.1	-6.7	-2.2	0.0	-6.4	-9.3	0.2	-18.7	-2.8	-10.1	-22.0	-18.0	9.0	1.9	-1.0	-6.1	2.1	-7.7	1.7
357	-17.8	-6.1	-7.8	0.6	2.2	-11.1	-8.2	-3.3	-19.9	-4.4	-10.7	-25.4	-22.0	4.6	3.7	-1.2	-6.4	7.7	-4.4	0.5
358	-8.3	-3.3	3.9	5.0	0.0	-11.8	-0.5	-1.9	-16.5	-4.9	-4.0	-15.7	-16.0	5.3	0.8	0.7	-9.1	7.8	-3.4	1.1
359	0.0	-1.1	6.1	3.3	-2.8	-3.0	-2.6	-3.6	-13.9	-5.6	-1.0	-9.6	-19.1	8.1	0.6	8.9	-12.0	7.4	-17.3	1.9
360	4.4	-4.4	-1.1	2.8	-1.7	-5.0	-7.0	2.7	-7.9	-5.1	-1.3	-9.9	-23.5	3.3	5.8	4.8	-11.3	8.3	1.9	3.1
361	0.0	-7.8	-3.3	5.6	-5.0	-3.3	-13.9	2.6	-8.0	-17.6	-8.5	-11.1	-26.9	-3.9	1.9	3.4	-11.2	3.4	0.8	1.4
362	-6.1	-11.1	-3.3	1.7	-6.7	-0.3	-19.2	0.4	-6.1	-21.3	-1.8	-13.3	-26.5	-5.0	2.3	-3.6	-5.8	1.4	-28.9	-4.4
363	-8.3	-18.9	3.9	2.8	-10.6	-6.0	-23.0	3.6	4.4	-19.0	-1.7	-14.4	-27.4	1.1	3.5	-7.2	-1.0	3.8	-20.4	-7.6
364	-11.7	-20.0	1.7	-0.6	-12.8	-10.6	-24.8	0.6	4.9	-22.8	3.8	-7.2	-23.5	-0.1	2.0	-11.6	-11.6	1.4	-15.1	-3.5
365	-1.7	-11.1	0.6	-7.8	-7.8	-11.5	-18.6	-2.9	-0.6	-21.9	3.1	3.2	-12.0	0.1	-2.6	-10.6	-18.8	0.2	-20.2	-2.4

TABLE C-3 MINIMUM TEMPERATURE DATA

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	-4.7	-4.2	-8.9	-0.3	-15.3	-15.1	-8.7	-19.5	-9.4	-8.2	-25.7	-3.3	-1.7	-8.9	-4.9	-5.4	-10.3	-14.9	-0.6	-22.9
2	-10.6	-13.1	-10.3	-6.1	-18.3	-19.4	-10.2	-22.5	-5.8	-11.1	-27.4	-7.7	2.3	1.5	-7.2	-1.9	-11.4	-4.5	-7.4	-20.1
3	-16.7	-25.3	-8.6	-4.2	-18.6	-16.8	-14.3	-20.9	-10.3	-6.9	-26.7	-3.4	1.9	3.6	-9.2	-3.9	-19.2	-5.8	-11.2	-18.6
4	-9.8	-23.6	-13.9	-10	-17	-19.1	-18.7	-20.4	-11.8	-1.8	-29.6	-5.1	4.8	-2.1	-8.4	-2.1	-19.7	-4.8	-14.1	-17.6
5	-2.8	-21.1	-15.8	-10.9	-24.8	-9	-20.2	-13.7	-20.6	-0.3	-28.2	-5.4	3	1	-11.3	-6.8	-17.6	-12.3	-9.7	-22.7
6	-2	-20	-9.2	-12.3	-28.7	1.7	-22	-14.7	-28.3	-4.9	-22.1	-5.2	0.2	-1.6	-9.9	-6.6	-16.6	-18.9	-1	-27
7	-8.9	-25.3	-12.5	-19.7	-31.7	-7.7	-24.2	-12.4	-28.4	-0.3	-22.2	-2.4	-4.5	-9.6	-3.1	-5.6	-17.1	-23.3	-1.8	-26.3
8	-8.6	-20.6	-20	-21.7	-26.4	-13.5	-22.6	-9.5	-28.5	-5.9	-24.7	2.5	-6.5	-10.9	0.4	-5.6	-19.6	-27.4	-1.5	-27.9
9	-4.2	-13.6	-24.5	-26.4	-22.5	-18.6	-16.5	-15.2	-29.8	-7.3	-23.4	-4.1	-12	-15.9	-0.9	-5.1	-13.3	-25.2	-2.3	-25.7
10	-12.8	-10	-28.7	-28.9	-12.3	-18.8	-13.9	-18.8	-28.1	-4.9	-23.5	-13.7	-9.6	-18.8	2.4	1.1	-15	-17.9	-2.3	-19.1
11	-17.5	-10.3	-28.9	-24.5	-11.7	-16.9	-17.7	-22.8	-28.1	-4.4	-19.3	-13.7	-9	-12	2.1	2.8	-15.6	-8.1	-6.4	-11.7
12	-29.2	-7	-27.8	-14.2	-15	-16.9	-15.4	-24.9	-21.1	-1.4	-18.8	-1.3	-6.4	1.1	-0.7	-0.4	-16.1	-2.8	-7.8	-7.3
13	-30.8	-0.9	-25.6	-4.2	-15	-18.5	-10.3	-26.7	-13.1	-2.9	-6.7	-2	-16.8	-1.5	-0.8	-6.2	-14.1	-1.4	-3.7	-2.5
14	-25.6	-1.7	-26.2	-4.7	-17.8	-22.5	-14.3	-23.2	-10.4	-4	-11.3	-6	-18.1	-3.4	2.3	-14.1	-8.3	-10	0.6	-0.6
15	-5.6	-7.8	-26.7	-7.2	-8.9	-19.8	-15.3	-21.9	-6.8	-8.2	-25.9	-3.4	-9.1	0.2	-1.4	-10.5	-3.8	-7.4	-1.9	-1.8
16	0.3	-13.4	-23.7	-7.5	-1.1	-14.4	-20.8	-14	-3.8	-3.5	-21.4	-7.2	-16.7	-0.8	-3.1	-6.9	-7.9	-4.1	-6.3	-0.4
17	-15.3	-11.7	-15.6	-2.5	3.6	-6.2	-22	-6.7	-7.1	-7.7	-16.4	-12	-21.5	-2.9	-3.9	-1.4	-7.7	-2.6	-7.6	2.1
18	-30.9	-7.5	-5	-5.8	0.3	1.1	-22.6	-4.5	-10.6	-3	-24.5	-5.3	-17.7	-15.3	-2.7	0.8	-9.4	-1	-4.2	0
19	-30.8	-7	-7	-2	1.4	-1.3	-21.1	-3.1	-8.7	0.5	-30	-4.5	-17.8	-21.2	-4.3	-4.6	-9.2	-3.6	-3.5	-4.5
20	-27	-2	-7.5	2.2	1.7	-0.4	-14.6	-7.3	-3.5	4.1	-32.2	-10.4	-10.1	-19.9	-9.1	-0.4	-2.9	0	-1	-3
21	-25.6	-2.5	-11.7	-2.2	-4.8	0.5	-5.7	-12.9	-3	0	-31.8	-9.8	-9.4	-9.6	-10.8	-4.1	-1.3	-3	0.1	2.9
22	-24.2	-2.8	-14.2	0	0.6	0.6	-3.4	-14.8	-0.4	0.4	-26.4	-11.6	-3.6	-4.8	-14.6	-6.3	0.3	-8.8	-1	-1.4
23	-28.7	3.1	-15	-0.3	-3.6	-0.5	-3.9	-3.9	4.9	3.1	-25.4	-19.8	2.4	0.4	-11.3	-5.7	1	-10.6	-2.4	-6.4
24	-31.4	0.6	-3.9	0	-11.1	-1.2	-8.6	-7.4	-5.1	0.2	-19.9	-25.9	-5.6	-1.5	-5.2	-9.7	-2	-9.5	-3.5	-8.2
25	-35.3	-6.1	-5	-4.7	-15.6	-0.6	-14	-11.2	-15.5	-0.7	-8.5	-21.4	-9.5	-3.3	-4	-5.3	0.2	-3.3	0.5	-5.1
26	-35.6	-10.9	-9.2	-9.2	-7.8	-0.5	-13.6	-11.9	-20.5	-3.4	-12.1	-17.6	-13.5	-4.1	-2.9	-4.6	-2.6	5.4	-9.2	-2.9
27	-27.8	-11.7	-19.5	-9.2	3.9	-13	-18.8	-6.9	-23.3	-6	-22.3	-14.3	2	-8.6	-0.8	-6.8	-2.9	3.5	-14.6	-7.9
28	-11.4	-11.7	-20.3	-11.7	0	-19.1	-18.4	-11	-22.9	-9.3	-18.6	-7.7	3.2	-11.9	-5.2	-4.6	-11	1.5	-19	-16.2
29	-6.7	-7.2	-25.6	-13.6	2.8	-15.6	-21.7	-14.5	-22.7	-8.4	-22.7	-6.8	-0.5	-24.5	-11.9	-3.7	-19.6	4.6	-26.3	-8.9
30	-5.3	-8.9	-29.5	-14.2	3.4	-9.6	-20.2	-16.6	-15.6	-8.8	-17.9	-6.2	2.3	-24.6	-11.2	-4.3	-23.4	-11.6	-29.3	-6.7
31	-10.3	-5.3	-28.9	-18.1	7.5	-9.7	-24.7	-19.6	-14.3	-8.4	-9.7	-7.9	4.6	-23.6	-5	-2.2	-26.1	-30.2	-30.6	-4.8
32	-15	-3.1	-24.2	-19.8	3.9	-3.2	-25.6	-22.5	-10.5	-9.6	-12.6	-7.1	2.2	-26.9	-6.8	-6.1	-21.1	-34.2	-26.8	4.3
33	-13.7	-4.8	-22.5	-21.1	1.4	-0.7	-20.1	-21	-3.2	-7.3	-22	-9.2	2.1	-24.5	-3.2	-4.7	-23.8	-33.5	-18.7	6.4
34	-15	-4.8	-13.9	-24.7	-10.9	2.4	-21.9	-20.7	0.5	-2.7	-21.4	-10.4	1.8	-24.4	-3.6	-6.9	-23.7	-26.3	-5.7	3.1
35	-17	-10	-13.9	-26.7	-12.5	-2.4	-19.2	-20	0.1	-3.6	-21.8	-13	-3.9	-15.5	-6.2	-2.4	-25.2	-16.5	-3.9	3.9
36	-19.2	-14.5	-9.5	-22.5	-10	0.6	-12.1	-20.8	-4.6	-8.2	-15.9	-14.2	1.8	-14.5	-10.1	1.5	-22.2	-9.6	-2.4	4.1
37	-21.4	-13.1	-3.6	-13.1	-0.8	-1.6	-7.9	-20.5	-5.4	-11.2	-6.9	-13	0.2	-21.9	-9	2.1	-16.2	-7.2	-4.4	1.5
38	-18.1	-11.1	-3.4	-18.1	0.9	2.4	-11.8	-22.9	-3.5	-17.3	-17	-14.9	0.7	-25.4	-14.6	3.9	-15.5	-13.3	-6	2.8
39	-13.7	-11.7	1.1	-20.6	3.4	3.5	-11.6	-27.4	1.8	-17.9	-21.5	-11.9	3.3	-24.3	-15.6	1.4	-18.6	-12.5	-12.2	-0.3
40	-7.3	-15.9	2.5	-17	-7.5	2.9	-11.8	-23.1	-3.2	-22.4	-16.7	-13.4	-1.3	-26.7	-15.2	-0.1	-22	-3.7	-14.7	-4.3
41	-4.5	-15.6	3.1	-22.2	-12.5	-0.8	-12.7	-24.1	-7.9	-20.5	-10.6	-12	1.1	-25.6	-12.3	2.1	-18.1	-4.9	-2.5	0.7
42	-2.5	-18.6	-2	-26.7	-2.8	0.8	-18	-23.5	-5.3	-16.4	-14.7	-9.1	-1.2	-22.5	-10.2	-1	-3.3	-6.1	-8.9	2.5
43	-5	-23.3	-11.4	-26.1	-7.3	-0.4	-16.9	-26.9	-10.3	-14.4	-19.4	-4.1	-1.8	-15.5	-11.6	-2.9	0.8	-2.7	-22	1.6
44	-5	-23.1	-16.4	-22.5	-9.5	3.3	-15.3	-24.5	-18.5	-10.4	-16.5	1.7	1.9	-9	-17	-6	-7	-9.4	-23	-5.3
45	-13.9	-22	-11.1	-20	-6.4	1.3	-15.5	-27.8	-17.5	0.4	-15.2	2.4	1.1	-5.6	-9.1	-6.5	-9.5	-17.7	-18	-7
46	-9.7	-17.5	-2.5	-13.6	-6.7	3.5	-16.2	-28.2	-15.3	4.5	-15.7	-0.1	-3	-1.2	-17.5	-5.1	-0.7	-24.9	-22.4	0.6
47	-5	-1.7	-4.7	-4.2	-9.2	0.2	-12.6	-27.6	-13.2	4.2	-12.4	-11	-1.5	-3.3	-24.1	-2.3	-0.5	-24.6	-25.6	1
48	-3.6	1.7	-3.4	-8.1	-7.2	1.4	-7.1	-23.5	-12.5	3	-2.7	-12.4	-2.3	-7.7	-26.8	0.3	2.6	-23.2	-26.6	-1.5

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
49	-12.5	-0.3	-3.9	-1.7	-10	2.8	-0.8	-18.3	-11.1	4.3	-2.6	-10.4	-2.9	-1.1	-26.8	-0.2	1.9	-19.5	-14.5	1
50	-18.3	-2	-4.2	-2.8	-12.8	4	3.5	-12.9	-13.1	1.8	2	-5	1.2	2.1	-25.7	0.4	2.9	-13.3	-2.7	3.2
51	-19.8	-1.7	-3.1	-3.7	-9.2	3.3	4.2	-11.4	-15.4	3.7	0.1	-2.4	5.2	-4.9	-23.5	0.7	7.4	-9.6	-0.7	-1.5
52	-21.2	5.6	-3.7	-4.7	-2.8	5.6	3.7	-16.1	-12.8	4.2	-6.3	1.3	3.3	-2.1	-18.6	-1.7	0.2	-8.3	-2.2	-7.7
53	-18.6	3.9	-5.9	-0.6	3.4	4.2	2.5	-20.5	-9.5	5.2	-8.2	-0.7	0.9	-6.1	-14.4	-1.8	-8.9	-5.5	4.9	-6.8
54	-17	-1.9	-8.1	3.1	3.3	1.8	-0.8	-23	-4.1	-1.1	-13.3	-0.3	-0.5	-5.6	-13.4	-5.7	-11.4	-2.4	-4	-6.1
55	-18.9	-4.5	-6.7	-1.1	-0.3	0.7	-8.7	-22.4	-5	-2	-22.2	4.3	-2.3	-2.3	-1.5	-9.5	-0.9	-5.2	-5.6	-4.6
56	-21.2	-10.3	-7.5	-4.7	-3.4	-0.2	-13.8	-17.7	-2.9	-5.2	-22.7	2	-3.5	-7.7	5.1	-10.1	4	-13.1	-1.6	-0.5
57	-25.6	-13.1	-11.2	-5.9	-8.4	-3.3	-7.8	-15.3	-4	-5.4	-18.2	-3.7	-2.8	-1.8	5.4	-11.1	5.2	-10.8	-4.6	1.9
58	-23.7	-10.6	-13.7	-2.8	-17.2	-2.1	-12.1	-17.2	-3.6	-4.2	-14.4	-8.1	-3.6	5	1.9	-10.5	2.5	-11	-0.3	-0.2
59	-20.9	-9.2	-11.4	-4.2	-19.5	-0.5	-16.8	-19.3	-8.3	-1.4	-16.4	-8.1	-3.6	3.7	7.1	-10.2	1.7	-19.8	3.7	-11.8
60	-25.9	-5.9	-9.8	-4.5	-22.5	1.2	-17.1	-16.3	-1.9	-1.4	-17.2	-6.6	-1.1	-6.8	6.7	-12.4	-2.5	-19.1	3.8	-23.7
61	-23.9	-4.5	-10.6	-5	-23.9	0.4	-13.7	-13.1	-8.4	1.7	-16	-6.8	0.6	-13.2	5.8	-8.4	-1.1	-18.7	4.9	-20.6
62	-21.2	-4.4	-9.5	-5.9	-22.5	-1.7	-16.5	-5.3	-18.8	1.1	-16.7	-5.1	1.4	-9.5	3.1	-10.3	-0.7	-17.2	3.5	-18.9
63	-16.7	-2.8	-0.6	-6.9	-15.9	2	-16.9	1.5	-17.6	0.3	-14	-7.6	-0.8	-10.4	5.4	-0.4	3.1	-17.1	0.8	-16.1
64	-13.4	-0.6	-8.9	-7.5	-5.6	4.8	-14.2	5.6	-12.7	-2.6	-8.3	-5.9	1.7	-9.8	-2.2	-6.6	4.2	-13.4	-1.7	-14.5
65	-12.3	-2.3	-17.8	-10.9	-2.3	3.2	-9.9	5.1	-8.4	-6.3	-6.2	-5	-2.1	-8.4	-12.2	-3.2	2.2	-7.9	3.1	-10
66	-14.2	-4.2	-18.9	-16.4	0.6	4.5	-4	4.9	-8	-4.4	-13.2	-4.9	-8.2	-4.4	-8.8	-8.4	3.9	-6.3	0.6	-0.7
67	-16.7	-2.2	-18.9	-16.1	2.2	5.5	2.3	-1.3	-3.2	0.3	-10.8	-6.1	-6.5	2	-8.1	-12.7	6.5	-2.7	1.5	0.3
68	-12.8	2	-13.9	-13.3	-2.2	2.8	3.9	-1.8	-8.5	2.2	-2.2	-0.6	-0.8	-0.4	0.3	-11.1	4.8	-3.5	-1.1	-2.5
69	-5	-2	-10.8	-12.8	-7.3	0.9	2.6	7.3	-12.1	4.9	-3.1	0.4	-5.3	-0.4	-0.7	-12.3	2.6	-13.5	1.2	-7
70	1.4	-5.6	-7.2	-8.9	-8.6	0.6	-0.3	4.4	-8	5	-2.8	2.2	-12.3	-0.5	0.5	-9.3	0.8	-19	-2.7	-12.8
71	3.1	-4.2	-5.6	-5.8	-5	5.3	-4.1	1.8	-9.7	3.5	-5.6	3.3	-13.4	1.3	-1.5	-5.8	-0.3	-15.7	-4.6	-7.7
72	5.6	-0.6	-9.2	-2.8	-5.3	-1.6	-3.3	1.3	-12.1	4.6	-2.7	1	-11.8	2.9	0.4	-3.7	4.3	-11.3	-2.2	-5.2
73	5.3	-1.7	-13.7	-1.7	-5.9	-5.6	-0.6	-2.2	-12.3	6.2	-3.8	0.2	-13	2.5	2.1	-4.5	3.5	-8.7	-1.1	-2.4
74	6.2	1.7	-15	-1.4	-3.1	-4.5	-3.3	4.7	-12.2	8.2	-5.3	-0.4	-15.8	2.3	1.4	-4.8	-0.7	-13.1	3.8	-3.7
75	6.1	3.4	-9.8	-1.1	2.8	-3	-1.4	3.2	-8.1	5	-9.1	-2.5	-8.2	4.6	1.5	-5.6	-0.9	-16.3	2.4	-0.9
76	4.5	-0.6	-8.4	-1.7	6.7	-0.7	2.1	3	-1.3	2.5	-8	-2.2	-6.4	6.6	0.6	1.2	1	-16.3	0.9	0.9
77	2.8	-4.2	-4.8	-4.8	4.8	-5	2.4	3.8	2.2	1	-10.8	-7.3	-0.1	4.6	0.3	-0.6	5	-14.6	2.9	4.1
78	0.9	2.3	-8.9	-3.9	-3.1	-8.8	1.7	4.2	1.5	-3.5	-4.9	-7.5	4.2	4.9	4.4	-0.2	4.1	-9.8	5.4	2.5
79	2.8	0.9	-5.9	-4.2	-4.7	-3.5	6.6	2.8	0.6	-12.3	-1.5	-5	3.1	2	6.8	-2.6	7.8	-8.7	-5	2.3
80	2	2.3	-11.1	-3.1	1.4	-7.9	3.7	4	-0.9	-10.8	0	-8.9	2.7	-0.5	8.1	-2.6	4.1	-6.3	-9.6	2.3
81	2.5	1.4	-16.2	-5.9	1.2	-9.9	0.9	2.2	1.3	-5	0.9	-8.9	6	0.4	3.5	-4	3.7	-4.4	-9.9	-0.2
82	-0.3	2.3	-16.1	-8.4	1.4	-7.7	1.4	5.1	1.3	2	0.1	-8.3	7.5	-0.7	1.6	-2.6	4.3	0.3	-8.9	-2.1
83	0	3.9	-10.3	-8.6	0.9	-6.3	1.2	-0.6	-1.6	3.8	-1.4	-6	5.5	2.6	-5.1	0.4	2.4	2	-1.4	-6.5
84	-1.1	5.6	-9.2	-5.9	0.9	-1.5	2.6	-9.8	-1.9	5.5	-3.3	-5.8	2.8	0.1	-0.9	2.3	3.7	-2	-1.6	-6.1
85	-0.6	-0.6	-9.2	-7.5	1.7	2.4	2.3	-6.2	-3	5.2	-1.3	0.9	1.8	-0.7	7.7	-2.1	4.1	-4.8	2.7	-6.9
86	-0.8	-1.4	-6.9	-8.6	2.2	0	3.7	-6.3	-1.6	5.6	1.1	2.7	2.9	-2.3	8.5	-13.5	-0.4	-1.8	6.1	-0.6
87	-2	0.9	-2.5	-6.4	1.4	-3.5	7	-3.3	2.2	8.9	-1.2	2.2	5	0.5	7.8	-8.8	-2.8	-2.6	5.5	3
88	-0.3	3.6	-2.3	-1.7	2.3	-0.8	3.9	-5.7	3	5.2	-2.4	0.8	6.1	1.3	6.8	-0.4	-3.9	0.1	8.3	4.9
89	2.8	5.8	-1.4	-5	6.1	0.7	2.7	-9.3	1.8	4.6	-10.5	1.3	5.2	3.2	5.2	7.6	-0.7	3.2	8.2	6
90	4.7	5.3	0.6	-14.2	2.8	1.1	1.6	-8.4	1.6	6.3	-14	3.9	4.2	6.4	2.7	3.9	8.4	2.7	5.8	7.8
91	-1.7	5	-2.3	-13.6	1.1	-1.2	-0.6	-5.3	-0.2	3.4	-12.1	4.8	4.8	9.2	1.7	2.5	5.9	3.5	5.6	9.1
92	-9.5	5.9	-1.7	-10.3	2.3	-9.1	-0.3	-7.7	1.8	4.2	-16.2	4.9	5.8	4.2	2.2	8	3.7	3.9	8.1	8
93	-9.5	6.7	-1.1	-10.8	6.1	2.1	2.3	-5.4	3.6	4	-15.7	4.4	6.6	1.6	6.7	9.8	8.4	3.8	5.5	7
94	-1.7	5.9	1.2	-10	7.5	10.2	6.3	-9.5	5.6	4.1	-13.4	5.2	7.3	2.5	9.1	8.5	4.7	4	0.2	7.6
95	5.8	0.6	0.3	-8.4	9.2	11.3	2.2	-10.6	4.2	7.2	-8.5	6.6	7.5	2.2	9.1	8.3	4.4	2.4	4.3	4.4
96	5.3	-2.8	-0.8	-7	11.2	11.8	-1.5	-1.5	0	2.7	-7.4	8.9	7.3	0.9	8.9	6.1	5.8	2.7	4.8	1.5

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
97	2.8	1.1	3.1	-5.6	11.9	12.1	6	1.9	3.1	1.1	-7	7.3	5.5	2.4	8.3	7.9	3.9	1.4	1.4	3.5
98	1.7	-0.9	3.6	-1.7	11.7	14.7	6	7.3	3	2.3	-0.3	-0.4	6.3	9.7	15.3	0.8	3.2	-1.3	-3.4	2.7
99	0.3	5.3	3.6	-0.3	12	10	6.3	5.4	3.3	1.9	-3.9	-3.1	6.1	7.7	6.1	3.8	5.5	1.9	-7.8	3.6
100	0.9	9.5	4.5	0.8	9.8	7.6	7.8	2.1	4.1	2.8	3.9	-4.7	6.1	10.2	-2.2	3.6	10	4.6	-6.2	4.4
101	4.5	10	5	5.6	13.1	7.1	6.5	-0.8	7.4	-4	2.8	-5.2	5.6	3.1	-9	4.3	7	8.2	-0.7	4.9
102	2.2	8.6	1.4	7.2	12.5	8.2	2.5	-2.8	8.8	-9.7	0.7	-0.9	6	9.2	-9.4	4.9	4.7	9.2	2.7	7.5
103	4.5	2	4.5	5.9	5.9	11.2	-0.2	-2.5	12.1	-4.5	6.3	4.4	8.6	12.6	-6.7	7.5	9.4	5.8	4	10.6
104	7.5	-2.8	3.9	1.7	6.1	6.8	-1.5	-0.7	9.5	5.7	1.1	6.2	12.1	8.5	-1.8	9.3	12.4	8.1	6.4	9.3
105	2.2	-1.7	5.8	0.9	3.9	7.5	-0.7	1.7	12.3	8.4	3.2	6.4	17.5	2	4.6	7.9	14.7	4.5	0.8	5
106	0.6	1.7	8.1	2.3	0.6	5.9	3.8	1.4	11.7	5.4	3.6	8.6	17.9	6.9	3.1	10	8	-7.1	2.6	4.5
107	0.6	2.3	8.3	4.2	3.9	6.3	3.8	1.2	15.7	5.6	4.7	11.7	8.9	8.5	7	6	4.5	2.5	8.6	4.4
108	2.8	5	6.4	5.3	6.1	3.9	6	2	11.7	6.4	3	13.5	6.3	7.8	8.4	3.8	7.6	7.9	12.4	7.7
109	9.5	5.3	5.3	4.5	6.2	4.1	5.4	1.5	15	10.3	2.9	12.2	6	4.8	8.8	4.5	6.3	7.8	13.5	10.3
110	5.6	5.3	3.6	1.7	7.2	3.9	8.7	3	10	12.9	6.2	13.8	9.7	1.7	12.8	6.3	5.1	13.2	14.9	11.8
111	3.9	4.5	5	3.1	5	2.8	7.9	0.8	8.8	10.7	10.6	14	13.2	-2.2	10.1	10	7.2	12.4	12.9	10.6
112	0.6	8.1	9.8	7.2	3.1	8.1	6.7	1.9	9.2	10	11.7	10	10.3	0.9	5.1	6.5	7.2	5.3	11.3	13.1
113	-0.6	6.1	8.6	8.4	7.2	14.4	7.1	4.8	15	13.5	9.3	11.7	6.9	3.8	4	5.4	7.4	3.6	8.8	13.8
114	7.2	3.9	10.6	7.3	11.4	17.7	9.1	5.1	16.4	10.9	4.9	13.2	3.7	4	4.6	10.3	0.8	6	9.6	11.7
115	8.6	3.6	15.9	11.1	7.8	18.8	9.4	8.9	13.2	6.5	6.8	5.7	3.4	2.9	7.3	7.9	1.7	5.8	6.6	7.2
116	8.9	8.4	12	11.1	9.2	20.9	14.2	7.2	18.4	6.8	9.4	2.7	4.1	5.3	9.9	8.9	7.5	5.8	1.9	4.8
117	12.5	4.8	7.3	6.1	12.2	8.8	17.5	9.4	20.2	7.8	10.8	2	3.1	5.6	8.2	16.8	12.8	8	1.7	6.9
118	17.8	1.1	10	6.4	9.7	12.5	11.6	7.8	19.6	11.3	11.9	4.8	5.1	5.9	3.6	16.2	13.9	10.2	0.6	5.7
119	8.4	1.9	9.5	2.8	11.9	13	12.5	7	15.8	9.6	8	10	4.1	5.6	3.2	15.2	14.9	11.4	2.4	6.7
120	5.9	3.1	4.2	6.1	14.8	7.9	11.6	5.8	12.4	10	7.8	4.2	5.1	7.6	0.1	17.5	10.2	13.2	7	3.7
121	6.9	6.4	0.3	3.7	11.4	11.8	14.3	1.2	16.9	14.9	12.4	4.8	10	11.7	0.8	16.6	8.4	11.3	8.2	3.5
122	10.3	10	0.6	8.6	12	16.3	11.3	0.7	19	9.3	12.9	6.3	11.1	17.1	8.9	9.1	7.7	6.8	8.8	4.9
123	10.3	9.7	6.4	8.9	14.5	14.7	8.6	2.6	11.3	7.4	9.4	8	7.6	17.5	10.8	11.3	4.8	10.7	10.5	4.6
124	7.5	6.7	11.2	6.7	12.2	12.1	7.5	2.1	13.1	9.2	2.9	11.7	7.4	11.3	5.9	13.4	7.1	9.5	13.5	7.5
125	5.3	7.8	13.1	5.6	8.9	8.1	8	1.9	12.1	7.8	3.5	10.6	7.9	9.9	8.3	11.1	12	14.1	17	7
126	8.3	12.3	11.2	7.2	11.7	7.3	9.3	4.4	11	7.7	4.8	11.7	4.3	9.8	7.8	14.1	9.9	15.1	12.4	9.2
127	8.6	9.5	12.8	10	14.8	12	10.3	6.1	12.2	11.8	2	13.6	5.9	13.6	11.4	20.1	12.4	15.6	3.3	13.7
128	9.5	7	11.2	12.5	13.9	16.2	11.9	6	13.4	9.3	4.7	9.7	8.9	11.9	10.3	15.9	15.1	15.9	5	11.6
129	10.9	8.9	8.4	13.4	14.2	18.8	11	8.9	12.5	7.5	6.7	6.4	5.5	13.3	9.6	13.6	16	19.4	8.8	11.6
130	11.4	9.5	7.5	13.1	19.7	16.6	6	10	12.4	9.6	8.8	5.3	6	11.5	8.8	10.2	16.5	19.2	5.5	14
131	14.2	9.7	7.5	15.3	11.1	14.4	4.4	10.7	13.2	10.8	14	9.6	6.5	7.1	7.3	15.6	16.6	12.3	4.7	16.4
132	16.1	12.3	7.3	13.9	12.5	13.4	11.1	10.1	12.3	12.5	14.3	10.9	9.9	9.6	9	11.1	16.1	10.5	7.6	16.4
133	17.5	16.4	8.1	10.3	11.1	12.7	11.3	10.7	12.8	13.2	12.8	7.5	11.9	11.4	10.6	8.9	19.9	9.7	7.4	10.5
134	14.2	18.6	9.7	13.4	10	12.9	14.2	11.3	14.5	12	16.7	4.3	15.4	10.9	5	15.6	11.4	12.8	7.7	10.3
135	10.3	16.2	7.5	12.8	12	6.8	11.6	11.7	16.7	8.8	17.9	8.4	11.6	12.7	5.8	11.9	11.8	16.3	8.3	11.1
136	10.6	20.3	6.1	10.6	15.6	2.2	10.6	6.9	17.3	9.9	14.1	8.9	8.3	15.7	7.1	10.2	16.9	15.7	10	14
137	10.3	17.8	6.1	12	13.9	3.6	12.9	9.6	19.2	12.5	14.3	11.4	9.5	18.9	12.7	12.4	15	11.8	10.1	17.5
138	8.1	14.7	6.7	10.9	8.9	6.5	13.9	10.4	18.5	16.8	12	11.7	13.2	15.5	14.1	9.1	11.9	11.4	11.9	17.1
139	12	16.7	7.2	9.5	10.3	9.8	16.1	8.8	16.1	16.4	11.1	12.3	13.6	17.3	16.4	1	11.8	3.8	11	15
140	17.5	8.1	9.2	10	11.7	13.1	19.1	10.4	18.1	17.3	12.5	11.9	11.4	17.7	21.6	3.9	13	4.5	13	17.2
141	18.6	12	12	12	11.4	14.6	18.2	10.4	12.5	17.9	16	12.4	7.1	19.4	11.2	6.1	14.2	5.6	12.6	13.3
142	15	15.3	12	13.3	15.3	12.1	14.5	13.6	16.2	16.3	16.7	13	9.7	20	7	10.3	19.1	4	12.7	10.3
143	12.8	17.8	13.9	10	18.9	14.9	9.9	19	12.6	14.8	12.3	8.2	6.5	15.1	10.8	13.1	19.1	4.2	17.8	9.1
144	12	19.2	12.5	7.8	13.9	16.9	8.5	18.7	8.6	19.2	17.3	12.8	6.1	11.9	16.7	14	12.4	6.8	18	6.3

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
145	10.3	16.1	16.1	8.3	14.2	14.4	5.9	17.5	7.6	18.7	12.2	19	8	9.5	21.5	16.1	15.9	8.6	19.2	7.6
146	12.8	12	13.9	10	13.1	14.8	10.3	20.2	9.1	14.6	9.8	13.9	9.7	11	23.8	16.6	15.1	10.9	16.8	11.5
147	14.8	12.5	9.7	11.4	20	11.5	14.6	14	6.7	15.3	8.9	15.2	11.4	14.2	21.9	16.4	18.4	6.9	16.3	13.1
148	18.9	9.5	6.7	10.8	12.3	8.3	13.7	7	9.3	13.8	8.6	18.8	13.8	12.5	22.5	14.2	17.5	7.3	15.9	13.1
149	19.5	13.9	7	14.7	9.7	8	7.4	9.1	10.2	15.7	11.4	20.9	15.4	13.3	23.8	13.5	16.2	11.3	20.1	15.4
150	21.7	18.7	9.8	14.7	12.2	11.9	9.3	8.6	8.3	16.9	13.2	16.7	15.1	11.7	24.7	16.3	10.1	13.6	15.6	15.9
151	23.1	9.8	12	13.7	12	15.3	11.7	13.1	11.3	13.3	15.7	15.4	9.8	9.4	18.6	12.5	12.5	15.6	14.7	16.9
152	17.3	12	14.2	15	12.2	21.7	16.1	16.2	15	16	14.2	12.8	11.6	10.1	22.4	13.4	13.1	16.7	11.2	14.4
153	14.2	12.5	16.2	17.8	11.4	11.9	19	18.6	15.1	18.2	17.4	8.5	14.5	12.1	18.5	12.3	14.1	14.7	7.1	12.4
154	17	13.9	12.8	14.7	11.1	11.9	21.1	17.4	13	14.9	17.1	8.3	14.4	8.4	13.3	14.1	17.7	14.5	11.3	10.5
155	16.7	13.9	10.3	15.3	10.3	15	23	17	10.9	14.4	17.4	9.6	15	14.4	13.9	16	17.7	18.7	12.4	12.8
156	19.2	15.6	13.6	15.3	12.8	16.7	19	14.7	10.2	14.6	10	14.8	16.4	16.6	14	19.7	16.9	21.1	14.4	12.7
157	18.4	17.2	13.9	12.3	12.5	19.3	13.7	8.3	8.4	13.1	7.1	16.3	12.3	16.2	18.5	16.2	17	15.7	13.7	15.4
158	19.2	16.7	11.7	10.9	14.2	23.9	16.2	11.2	11.1	12.2	11.7	15.1	11.7	14.7	16.7	13.7	13.4	14.9	15.5	16.1
159	20	15.3	12.3	13.1	17.8	20.9	18.7	11.3	16.8	13.9	12.4	17.9	12.4	11.5	17.6	18.1	15.8	17.7	16.2	14.8
160	15	11.7	13.1	14.7	16.4	13.9	13.4	13.5	20.2	13.3	13.2	17.1	10.2	10.5	17.4	21	16	13.5	15.9	15.2
161	15.8	9.2	13.4	16.1	16.7	8.8	12.8	15	21.4	14.2	16	18.7	12.9	10.1	20.2	15.8	18.6	15.8	15	18.4
162	18.1	12	17.5	16.7	15	11.8	11.6	18.9	19.6	12.9	17.9	14.7	16.5	13	12.2	17.3	10.6	15.8	11.6	14.9
163	12.8	16.1	18.6	14.5	14.2	15.4	15.4	17.8	17.6	12.9	20.8	13	17.5	16.5	13.2	20.4	11.5	18.1	12.2	15
164	10.8	18.9	15.6	13.4	11.4	17.7	16.8	11.8	19.5	15.1	22.3	16.4	18.8	13.9	11.7	18	15.1	19.1	11.4	11
165	11.7	13.9	16.7	15	14.2	14	10.6	9.4	17.7	15.9	21	17.1	21.1	15.1	14.8	17.4	13.3	18.8	11.6	10.5
166	16.7	10.6	21.4	12.8	14.7	14.6	15	11.7	20.1	16	20	22.7	17.7	10.6	12.8	17.5	18.4	16.6	16.8	14.1
167	21.1	11.1	22.3	13.1	12.8	16.5	14.8	12.2	22.3	11.5	19	20.4	15.5	13.3	12.6	14.4	19.4	14.3	15.1	13.7
168	12.8	14.2	18.9	12.5	14.5	16.9	17.5	15.8	15.2	10.6	16.7	21.4	12.3	13.2	18.4	16.1	20.1	14.9	16.8	12.9
169	11.4	15	18.4	13.6	18.9	18.8	12.7	17	14.8	12.6	20.4	15.5	10.8	17.8	18.8	18.9	19	15.6	17.5	12.8
170	13.9	15.6	19.2	15.3	17.5	21.2	12.7	16.5	16.9	12.6	21.9	10	10.2	20.1	13.7	20.9	16.1	13	16.5	13.1
171	18.1	16.4	19.7	14.5	13.3	22.5	18.8	14	18.9	13	23	13.1	13.4	15.2	14.2	19.9	15.6	10.6	16.4	13.4
172	18.6	19.2	22.8	18.1	13.9	19.7	18	14.2	18.6	12.5	24.7	13.6	15.2	13.6	17.4	17.2	16.4	15.1	17.1	13.8
173	14.5	23.4	22.8	17	11.1	17.8	15.7	15.3	18	14.7	18.9	12.9	17.3	13.6	18.7	15.3	20.3	16.5	21.2	15.3
174	16.4	23.3	22.8	18.6	9.2	16.7	13.5	15.7	16.1	14.5	15.4	12.6	18.6	12.2	20.9	13	17.9	14.5	22.8	15.2
175	15.3	17.5	17.5	21.1	10	21.1	17.6	12.6	15.7	15.7	14.4	16.7	20.4	7.7	15.7	14.8	15.6	12	18.4	15.7
176	12.8	14.8	15.6	17.5	10.6	15.8	19.2	15.8	15.9	18.4	15.2	12.5	16.1	11.8	13.6	17.9	19.2	11.4	19	14.9
177	16.2	17	14.2	13.4	9.5	14.9	18.5	18.2	17.5	17.4	17.8	12.9	16.8	13.3	13.6	20.2	19.6	14.4	19	19.2
178	15.9	19.2	14.8	9.5	13.1	16.6	19.7	20	13	14	16.9	14.4	19.3	18.9	15.5	16.2	20.1	13	18.1	17.9
179	18.1	17	13.9	9.2	15.6	16.8	22.3	21	13.1	14.6	17.2	18.1	19.5	20.3	16.9	16.9	18.9	12.9	17.2	17.5
180	15.9	15	15.3	14.2	18.6	13.3	22.3	23.4	13.2	18.3	17.4	19.2	21.7	16.6	16.8	18.9	16.1	16.9	17.7	16.6
181	13.4	11.7	16.1	17	20.6	14.6	21	21.1	15	18.2	16.4	17.3	15	16.4	16.2	16.9	16.9	18	20.7	16.5
182	10.3	12.8	13.9	18.4	17.8	16.7	19.1	14.6	17.1	16.6	19.9	17.1	14.8	19.4	18.3	17.5	15.8	15.8	16.4	18.8
183	12.5	16.1	14.5	21.9	15.8	14.7	20.1	13.9	19.4	18.9	17.6	15.1	16.1	21.5	19.1	22.8	16.9	15	13.5	19.2
184	13.9	18.6	15.3	24.7	16.7	14.9	20.1	14.2	19.8	22.6	15.3	19.5	16.9	21.6	15.1	18.5	15.1	16.7	10.3	19.9
185	16.1	19.8	15.9	24.2	20.3	14	21.9	17.9	18.4	20.9	13.6	19.1	17.2	22.9	13.3	14.3	15.1	15.7	11.9	18.1
186	15.3	15	14.2	23.9	18.1	12.5	18.6	20.9	14.8	19.2	15.4	19.3	18.5	22.5	12.8	13.2	13.5	15.2	16.2	17.1
187	13.1	14.4	13.9	25	19.5	12.1	13.7	23.3	12.2	18.5	17	17.1	13.3	21.8	14.5	14.6	11.6	18.1	14	12.6
188	14.2	14.5	14.8	17.8	22	15.2	12.9	19.8	17.1	10.3	17.3	17	12.8	19.6	17.3	16.2	16.1	19.1	16.4	15.5
189	15.6	16.1	16.1	19.5	21.1	15.9	15.5	18.7	21.3	15.8	16.1	17.7	16.8	21.2	18.9	15.5	17.9	12.6	18.9	16.9
190	15.6	16.4	18.1	21.7	19.2	17.8	15.9	20.5	20.5	14.5	17.5	17.9	17.5	23	16.5	13.9	15.4	15.6	19.7	19.5
191	12.3	21.1	17.5	23.9	18.1	14.9	17.9	17.5	18.9	15.9	20.2	17.6	19.2	23.6	18.1	12.4	16.8	15.3	19.6	17.6
192	13.6	17.3	15.6	26.1	18.6	16.3	13.2	14.7	17.1	17.4	20.3	18.4	19.3	20.4	15.5	15.6	20.1	15.7	21.9	19.1

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
193	18.6	16.4	11.9	25.8	17.2	12.3	18	13.5	16.3	19.6	20.8	16.9	18.8	15.4	13.4	17.5	15.8	17	24.7	21.4
194	17.5	15.8	15	20.6	17	12.1	18.7	12.3	18.3	20.5	20.4	19	16.9	14.7	12.8	20.4	15.1	19.7	21.1	22.8
195	16.4	19.2	18.1	19.8	13.4	13.4	19.7	15.2	18.9	15.4	15	15.4	17.5	16.9	16.2	20	13.7	21.1	17.6	18.6
196	17.3	18.1	23.3	18.9	16.7	15.3	21.7	17.5	18.6	16.7	12.1	11.5	18.8	17.6	14.8	16.2	14.8	21.8	17.5	19.1
197	16.7	15.9	18.3	17.8	21.7	17	20.1	20.4	16.4	17.4	15.3	13	19.1	17.2	14.5	10.8	16.2	19.4	16.1	19
198	14.2	15.6	19.7	16.4	19.7	16.7	14.9	22.8	13.4	19.3	17.9	14.4	20.3	15.4	13.7	12.8	15.5	17.7	13.9	18.1
199	11.2	16.7	21.4	13.9	17	12.7	12.9	24.7	13.5	21.7	18.9	17.5	18.1	17.7	15.9	14.3	17	19.4	13.5	17.7
200	13.9	19.5	21.7	17.2	17.3	11.4	15.7	25.8	11.9	22.3	15.8	20.3	15.7	14.1	16.3	12.9	18.3	21.9	12.8	16.5
201	15	23.9	16.7	17.2	20.3	15.9	17	23.2	16.3	19.8	12.7	20.7	13.3	19.3	18.7	15.8	21.2	22	13.3	16.2
202	14.5	19.2	17.8	16.4	18.9	21.9	18.3	20.5	20.3	18.2	16.1	18.5	13.2	23.4	20.6	15.4	23.1	18.9	15.7	17.1
203	13.6	14.5	21.2	16.4	16.9	19	19.6	18.5	23	16.2	13.6	18.4	16.7	18	21.3	16.3	17.7	16.6	18.2	17.3
204	13.3	16.1	19.5	17.2	20.6	17	20.9	16.4	17.9	17.7	17.7	21.7	19	15.1	14.7	18.2	16.7	17.7	18.6	18.8
205	16.7	15	19.7	21.7	19.5	17.3	19.7	14.6	13.3	14.6	18.3	21.6	21.8	16.7	17.2	20.5	20	16.2	18.4	21.1
206	15.3	17.5	15.9	18.6	19.5	22.1	20.1	15.3	16.6	14.6	18.9	20.6	22.5	17.1	15.4	22.2	21.5	17	20.6	23.9
207	15.6	19.2	15.8	20	16.4	22.1	22.3	18.5	17.2	18.3	18.8	16.9	25.5	15.7	15.2	20.6	22.9	19.7	17.5	20.2
208	19.5	15	15.3	23.6	12.2	21.6	19.1	19.6	17.9	21.4	20.8	15.5	24	17	13.8	23.3	17.7	20.8	20	18.9
209	18.6	16.2	17.8	17.2	14.7	17.5	17.5	21.4	15.6	18.2	18.9	18.5	22.7	16.9	14.1	24.5	17.3	19.7	17	18.6
210	16.2	18.9	20	15.9	15.3	13.9	18	15	17	14.1	21.2	18.5	23.2	18.2	12.9	23.5	18.4	21.1	17.7	15.7
211	15	22.3	18.9	15.3	16.4	15.7	18	16.8	16.3	15.4	23	19.1	22.5	18.8	15.1	23	17.5	19.2	21.7	14.8
212	16.4	22.5	15.6	15.8	16.7	17.6	18	20.8	18.3	16.5	19.8	23	23	21.2	17	19.3	16.8	22.2	22.4	17.1
213	14.5	21.4	15.6	17.5	18.4	17.7	10.6	20.3	20.5	17.4	20	23.6	24.1	22.3	18.3	12.3	14.3	24.1	20	17
214	14.7	20.6	18.9	15.3	22.8	18.7	13.1	17.5	14.5	18.6	15.6	24.2	23.9	22.8	20.9	13.5	16.4	17.3	16.9	17.4
215	18.4	18.9	23.1	13.9	20.6	16.2	17.5	12.1	10.3	19.3	12.3	20.9	22.5	23	20.7	13.6	18.7	16.1	16.8	21.1
216	14.8	21.1	22.5	17	19.2	12.4	21.2	14.6	13.4	19.2	15.1	18	22.4	21.3	17.9	16.8	20	18.3	19.4	21.7
217	17	14.5	19.7	19.2	18.9	16.8	19.2	17.3	11.7	20.2	16.4	22.1	21.7	17.5	16.2	16.6	14.9	15.2	22.1	22.7
218	20.6	11.7	15	15	19.7	13.1	19.8	16.2	13.4	21.7	18.7	21.3	19.5	16.5	17.7	17.8	11	17.8	24.9	19.2
219	21.7	17.5	14.5	17.5	20.6	15.7	20.4	16.6	12.7	21.8	17.1	19.4	18.2	16.8	20.1	20.3	14.1	20.8	18.9	21.9
220	22.5	18.9	14.8	14.5	18.6	15	21.9	15	14.1	22	19.5	22.5	20.9	9.9	16.1	17.5	16.5	20.8	19.1	24
221	20.9	21.4	16.4	15.3	18.1	11.8	22.8	15.4	17	22.3	19.5	22.3	23.9	10.3	14.4	13.9	16.9	22	20.2	25.6
222	18.1	18.9	15.9	14.7	19.4	14.2	23.4	18.4	15.6	24	21.1	25.4	20.6	12.2	17.4	10.8	16.1	19.8	21.1	21
223	15.6	16.4	13.9	13.9	20.6	15.6	18.1	17.9	14.6	22	14.5	22.9	19.2	13.4	20.3	10.4	16	19.6	21.6	19.3
224	13.9	20.3	11.1	15.3	20	13.8	15.6	15.5	16.1	19.4	13.8	19.5	22.8	11.9	20.7	9.9	17.7	21.2	22.5	19.1
225	14.7	21.7	10.3	11.7	21.1	11.3	15.4	13.1	17.1	16.4	15.8	18.5	16.5	13.2	19.4	9.9	19.5	21.8	18.8	18.8
226	18.1	20.3	13.4	14.7	22.8	14.7	15	15.3	18.8	20.4	13	18	15	13.9	16.3	11.8	16.6	21.6	18.1	20.2
227	19.7	17	13.7	13.1	22.3	14.5	14.5	17.2	16.4	22.2	11	18.2	17.5	14.2	13.6	14.2	14.6	18.8	18.3	20.2
228	20.9	17	16.4	11.7	20.9	14.1	12.5	18.8	17	22.2	14.6	16.9	19.7	13.5	13.9	14.1	15.7	17.3	16.3	21.4
229	21.4	11.4	16.2	11.4	13.6	18.8	10.4	20	15.2	21.5	17.8	16.9	22.8	16.7	17.9	12.8	15.6	15.4	15	21.6
230	19.2	7	17	11.4	17	20.4	11.1	19.9	14.8	20.3	17.2	12.5	18.4	17.9	20.3	13.1	16.7	16.1	15.6	23.6
231	19.2	9.2	8.6	12.8	15.8	17.6	8.3	18	15.8	24.1	17	13.9	14.2	17.2	13.6	12.5	15.4	14.7	17.9	21.4
232	16.7	13.4	11.1	14.8	15.9	18.3	9.2	20	13.6	21.2	17.8	13.8	13	11.4	14	11.8	12.9	17.1	20.9	19.1
233	18.7	15.3	13.6	16.4	14.5	11.5	11.6	17	13.2	19.7	18.1	14.7	15.4	9.9	14.8	12.5	15.8	15.9	21.4	17.8
234	19.2	18.4	14.7	12	17.3	10	15.5	16.7	13.7	20	14.6	17.8	21.2	13.2	15.9	12.9	15.9	16.5	17.4	17.1
235	20	15.3	13.7	12	16.4	9.3	13.4	18.1	12.7	21.1	15.8	18.4	18.5	19.3	18.7	14.4	18.3	13.8	10.1	17.7
236	20	13.7	13.9	12.2	18.9	10.8	12.1	13.1	9	23.6	14	18.4	17.8	21.2	12.6	14.6	18.1	15.1	7.7	14.9
237	21.4	16.2	11.2	10.9	15.8	13.4	15.1	14.5	10.2	23.5	8.7	17.3	16.9	15.1	11.8	11.4	16.6	12.3	9.8	14
238	20.9	16.7	13.1	13.3	11.1	10.7	13.7	14.5	13.9	25.9	7.1	17.8	21	11.3	15.2	12.7	13.2	14.3	11.4	14.9
239	20	14.5	14.7	16.4	13.3	11.3	14.3	18.2	13.3	22.9	11.1	18.3	15.3	12.4	18.3	17.4	14.2	11.4	13.6	17.3
240	20	14.5	13.9	18.1	15.6	13.6	15.5	17.1	10.8	17.6	11.6	19	11.5	13.9	20.6	13.4	17.5	10.8	18	16.6

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
241	17.5	14.4	15.9	13.4	17	11.6	16	15.3	11.6	13.6	8.2	18.2	10.9	15.3	19.3	11.9	20.2	8.7	18	14.8
242	11.4	10.3	12	11.7	17.3	11.1	17.2	16.5	13.4	8.7	9.2	18.9	10	12.8	16.8	13.6	14.5	7.5	15.1	20.9
243	12.5	8.6	11.7	10.9	17.8	5.6	18.7	18.2	11.3	13.1	12.4	20.3	14.3	13.5	13.6	16.6	16.5	9.7	9.9	18.8
244	13.7	10.3	9.7	11.1	17.8	8.4	17.8	15.8	11.1	15.4	15.2	18.6	11.7	12.9	16.3	16.5	18.2	13.1	13.1	14.5
245	15.3	14.2	13.3	12.2	13.1	9.3	17.6	17.7	10.6	8.1	19.7	15.8	8.6	11.3	15.9	14.9	20.6	11.7	14.5	11.9
246	11.1	15	15.9	10.6	12.3	10.4	16.5	15.1	12.5	10.5	18.4	16.2	9.1	10.9	13.5	13.6	20.4	14.4	13.8	12.7
247	9.7	15.3	12.5	11.4	16.9	10.1	13.8	15	13.3	12.1	10.4	13.7	15.1	11.9	9.5	16.1	22.1	14.2	15.4	11.4
248	7.5	18.4	7.5	13.3	14.2	12.5	11.8	12	16.1	13.4	10.6	8.2	17.6	7.6	8.6	15.8	22.9	11.4	16	16
249	3.1	20.3	7.3	14.2	9.2	12.6	13.1	13.2	18.8	16.2	14.7	9.9	12.1	2.8	8.8	12.6	16.4	12.7	15.9	17.4
250	6.4	15.3	3.9	16.7	7.8	12	14.9	12.3	11.1	19.5	18.2	11.2	6.1	4.2	10.1	10.8	11	12	17.8	13.8
251	10.6	14.7	4.8	12.5	10.6	12	11.5	14.1	11	20.9	16.4	8.3	7.1	6.9	11.5	13	10.5	8.9	11.9	7.8
252	10	14.5	5.8	10.8	15.9	11.3	13	11.4	16	22.6	16.6	7.4	8.3	9.7	13.7	16.1	8.9	4.6	13.5	9.3
253	11.1	15.3	2.5	9.2	12.8	12.2	14.3	11.2	16.5	17.2	11	8.5	7.9	10.9	11.7	14.8	8.4	3.2	16.7	10.9
254	10	18.7	5.6	9.5	10	10.8	10	8.7	12.3	16.7	9.4	9.6	9.1	12.2	6.5	16.7	9.5	8.7	15.8	13.1
255	9.7	7.5	8.9	13.9	7.8	15.8	7.4	11	7.7	14.2	5.7	10	6.8	14.2	3.4	18	15.9	13.6	12.4	14.6
256	12.8	2.8	16.7	15.9	11.7	15.8	8.3	13.7	7.2	12.3	5	11.4	9.7	12.4	4.6	12.3	16	14.7	13.2	13.3
257	14.2	4.5	17.8	15.6	15.6	8.7	12.4	18.8	9.2	12.8	7.8	12.2	9.6	11.3	5	12.1	17.9	14.8	16.8	9.2
258	13.3	6.1	17	13.9	15	8.5	11.3	19.7	7.2	17	12.6	10.9	13.3	11.9	7.1	11.4	15.3	10.6	18.1	9.6
259	8.9	8.1	17.5	13.1	16.1	8.3	7.1	15.8	7.1	20.5	12.2	7.2	14.9	12.3	7.2	10.2	8.7	8.7	15.4	8.1
260	6.7	9.5	15.3	7.8	13.9	6.7	5.1	14.1	5.4	22.7	15.4	3.8	14.2	5.6	7.2	9.8	5.2	5.9	11.1	3.6
261	4.7	10.9	13.4	7.8	12.5	10.8	6	16.2	4.8	21.1	14.8	2.3	14.1	3.1	6.9	12.5	7	7.3	12.6	7.9
262	4.5	10.6	12	9.2	13.1	12.8	8.2	12.6	7.7	15.5	14.1	3.5	11.5	3.4	7.9	13.1	7.1	12.3	12.7	15
263	3.7	8.7	11.4	12.2	14.7	14.5	11.3	13.1	8.6	11.4	16.3	4.9	9	9.3	8.5	15.8	4	11.1	12	10.7
264	-0.3	6.7	12.5	15	15.3	11.9	10.5	12.4	5	12.2	13.3	10.5	4	7.5	8.2	17	7.5	9.7	12	8
265	1.4	7.5	14.5	15.6	13.6	12.4	9.6	12.2	5.8	9.3	16	14.8	1.2	2.6	12	18.3	9.1	10.5	16	5.7
266	-2.3	7.8	14.2	18.4	15.8	11	9.4	12.8	9.7	9.1	16.2	13	1.2	1.7	13.4	13.6	6.9	13.9	18.5	11.3
267	-2.8	8.9	14.5	17.2	15.6	10.3	9.9	13.9	4.5	8.7	16.4	12.6	2.2	7.4	12.4	11.6	5.9	11.5	19.5	16.7
268	-0.6	8.4	18.1	12.2	14.2	10	8.4	15.3	8.9	6.6	13.5	15.7	1.8	9.9	10.2	13.7	2.2	15.1	14.4	16.8
269	0	10.3	9.2	11.1	13.4	8	9	13.4	8.9	7.6	7.1	17	1.4	6.4	5	11.1	4.6	15.9	11	14.3
270	0.8	16.1	4.7	11.4	16.4	8.5	8.8	12.9	10.7	5.8	6.6	4.4	3	0.9	5.4	9.7	4.7	15.5	7.8	16.1
271	2.5	14.2	2.2	11.4	15	7.6	11.3	11.7	12.7	7.7	4.2	1.4	5.2	1.5	5.9	12.8	8.1	13.2	8	15.1
272	7.8	10.3	0.3	9.8	15.9	8.8	13.5	9.9	16.3	8.1	5.2	5.2	7.7	4.3	8.5	14.9	17.6	15.6	9.9	10
273	13.9	5.9	-3.4	12.2	11.7	9.8	12	11.5	13.2	9.8	7.6	4.8	11.6	8.9	6	17.5	11.2	7.3	9.5	10.7
274	12.8	2.3	5.6	15.9	8.6	7.8	9.2	10.9	11.7	12.5	9.7	7.2	12	10.5	2.3	14.1	8.6	0.1	7.8	8.8
275	10.8	4.2	11.4	16.4	8.4	6.5	8.9	10.7	14.1	7	8.4	7.5	12.7	9.3	-0.3	18.2	6.7	2.7	7.2	7.2
276	8.6	9.5	4.8	18.4	3.3	1.3	10.5	11.4	16.1	5.1	4.6	8.8	13.8	7.4	8.7	13.7	8	7.8	4.4	5.7
277	4.5	6.9	-2	10.8	2.5	1.8	6.9	13	18.1	4.7	5.1	7.3	15.4	6	7.9	8.9	10.6	9.6	0.7	4.3
278	4.7	7.2	0	8.3	6.2	2.8	6.8	11.3	17.4	6.9	6.3	5.7	12.7	6.7	13.7	10.9	12.5	5	-1.9	11.2
279	13.6	2	7.3	5.3	7	3.2	10.8	12.5	17.8	9.3	7.4	7.1	12.5	0.6	14.1	7.6	11.9	9.5	-0.1	14
280	12	3.4	12.5	2	15	6.3	13.2	7	15.3	10.7	9.2	8.6	13.7	-1.2	4.8	7.4	13.7	11.4	2.6	10.7
281	10	4.5	16.9	3.9	13.4	6.1	12.6	5.6	12.6	5	7.1	7	19	-3.1	5.9	-0.4	13.8	10.6	4	7.7
282	1.9	4.2	15.9	5.3	14.5	-0.1	13.6	10.1	10.5	2.9	7.1	6.8	16.3	0.5	8.3	-0.4	14.6	9.9	9.4	14.1
283	-7	5.6	9.2	5.6	12.2	1.6	10.5	18.8	7.7	3.7	14	3.4	16.2	9.2	3.2	6.5	14.1	7.9	2.8	13.9
284	-2	7.3	5.8	5.6	10	8	8.1	14.4	10.2	2.5	11.8	8.4	12.8	9	6.6	14.2	12.6	7.3	0.8	15.9
285	7	6.7	10.9	6.7	10.3	11.9	7.3	14.4	6.1	1.9	9.5	10.5	10.9	6.2	10.2	10.9	14.8	4.8	6	10
286	3.1	5.8	5.8	8.3	7	8.1	7.3	14.8	3.6	4.3	17.3	9.7	8	4.3	9.3	6	13.3	3.6	6.3	3.8
287	5.6	4.7	5.8	8.3	0.8	7.2	9.9	12.3	3	9.9	11.6	6.4	6.1	2.7	12.4	4.2	11.5	3.1	3.9	11.5
288	9.8	4.2	14.5	7.5	0.6	11.7	9.2	6.3	4.8	11.4	10.3	1.4	1.6	2.5	15.2	3.9	7.3	0.8	1.6	9.9

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
289	2.5	5.3	12.2	7	1.4	9	9.7	5.7	4	10.1	7.1	0.9	-1.9	5.4	12.5	8.5	7.2	-0.9	0.2	-1.6
290	-0.9	5.9	9.5	10.3	1.4	9.8	8.2	6.1	11.1	7.3	0.6	2.4	-1.5	6.8	10.5	4.4	5.2	4.1	1.5	-5.7
291	4.2	7.3	13.9	6.7	4.2	9.9	14.4	4.2	11.5	10.5	-2.7	4.8	-1.3	6.3	7.8	3.6	4.3	10.7	6.6	-3.3
292	9.5	8.4	14.5	7.2	5	6.1	15.1	4.4	9.8	4.9	-2.7	8	0.6	8.2	7.1	-1	7.7	7.7	1.8	3.6
293	5.8	5.8	11.1	6.2	1.7	3.3	6.6	1.7	4.1	-0.8	0.2	7.8	-2.9	5.3	11	3.5	7.4	11	2.2	8.2
294	1.1	2.8	4.2	4.2	3.9	5.3	4.9	1.6	3.8	-1.9	2.4	7.5	-3.9	10.1	11.1	4.2	10.7	9	3.4	0
295	3.6	3.3	9.7	1.7	-1.4	9.9	2	0.9	2.6	-3.6	8.7	7.8	-0.2	8.6	11.2	4.3	2.6	8.4	3	-6.8
296	5.6	2.8	9.5	1.1	-0.8	14.3	8.9	2.2	2.3	5.2	10	4.9	0.7	6.7	10.3	1.3	6.9	4.9	3.6	-8.9
297	8.1	1.7	8.6	-1.1	-3.6	6.3	6.1	5.2	-0.6	1.5	10	3.2	-1.6	6.3	8.2	6.2	5.6	3.2	10.4	-5.2
298	6.7	2.2	7.8	0.6	-2.8	6.8	5	4.9	0.8	3.8	8.1	8.3	2.4	3.6	8.7	7.8	-0.5	7.8	8.5	-5.8
299	-4.2	3.1	8.9	-3.1	6.1	6.9	5.3	8	-0.7	-0.4	7.8	8.2	-4.7	-0.1	9.3	4.2	-2.4	6.3	1.4	-10.4
300	-4.7	8.1	6.4	-5.6	9.2	6.4	3.5	6.7	-2.1	0.8	6	3.2	-11.2	2	6.4	5.9	-7.8	-0.1	2.7	-15
301	-5.3	5	5.9	-2.8	8.4	7.3	0.9	4.2	4.4	4.4	6	3.3	-14.5	0.5	-0.4	11.3	-5.7	-1.4	5.3	-13.6
302	-5	5.8	3.9	-5.6	3.9	7.1	1.3	4.6	7.5	4	0.1	5	-15.5	0.4	-0.9	9.3	-2.2	3.3	2	-12.7
303	-1.1	4.7	3.3	-2.5	2.2	5.6	2.8	4.8	4.4	3.8	3.7	7.2	-16	0.2	-3	8.9	5.5	0.6	6.4	-10.9
304	7	0.6	3.6	1.4	5.8	4.9	5.9	1.9	3.6	11	5.1	7.1	-20.7	1.9	-5.3	6.8	3.5	-5.5	2.8	-13.5
305	3.1	-3.1	2.3	3.1	4.5	0.8	10.5	0.7	3.5	7.3	1.4	4.1	-20	0.5	-3.7	4	4.3	-2.6	-0.7	-15.3
306	2.5	-8.1	4.2	3.6	3.9	2.3	10.2	0.9	6.7	3	-2.5	4.8	-14.4	1.5	6.7	4.5	4.2	2.3	-3.8	-16.2
307	1.4	-13.4	6.1	10.3	4.7	1.5	5	-3.6	6.1	2.1	-3.7	3.4	-12.2	0.4	7.4	3.9	-1	5.2	-3.2	-7.2
308	-1.1	-12.5	5.8	7.5	7.8	-0.9	1.5	-2.6	7.8	4.6	2	6.5	-9.7	0.6	6.7	1.9	4.2	4	-5.5	-5.5
309	-4.5	-14.2	5.3	6.7	1.7	-0.6	-0.7	-3.4	9.7	8.7	3.2	4.5	-2.3	-1.4	3.9	2.7	2.8	4.7	-8	-13.6
310	-6.9	-15.6	2.5	2.5	0.6	1.3	5	-8.4	3.4	7.8	-0.2	2.1	-5.4	-5	-1.9	3	4.2	2.4	-2.5	-10.1
311	-3.1	-16.9	1.2	1.4	5	1.4	7	-4.9	2.5	1.2	-5.2	-1.2	-4.7	-10.2	-12.4	1.9	0.7	0.2	5.4	-0.4
312	-2	-18.6	3.3	0.9	5	-0.4	-2.5	-4.6	1.4	0.2	-4.1	-2.2	-6.4	-10.5	-17.3	3.3	-2.5	0.1	-2.4	-5.6
313	-2.8	-12	2.5	-1.1	3.1	-1.6	-9.6	-1	1.8	6.3	-2.8	-3.3	-8.7	-14.5	-18.1	3.7	-4.5	-0.4	-4.2	-7.8
314	-5	-12.5	2.3	-5.3	-3.1	0.6	-10.4	1.7	0.5	6.5	-2.2	-4.3	-7.7	-15.3	-15	6.3	-6.5	1.3	-5.8	1.2
315	-3.6	-12.2	-0.3	-2	-3.6	3.4	-5.8	1.6	-1.9	7	-9	-0.8	-10.4	-15.5	-16	7	-5.7	-3.5	-10.6	1.8
316	-3.9	-10	0	2.3	-1.7	6.2	-8.4	3.5	-1.8	6.4	-8.6	1.9	-10.5	-6.1	-18	5.1	-7.2	-5.3	-7.9	4.1
317	-2.3	-6.1	-2.8	8.1	-1.4	5	-5.4	4	-0.9	1.5	-8.1	-3.7	-15.2	-0.4	-9.7	1.8	-6.5	-7.8	-4.7	2
318	-2	-6.4	-1.1	5.3	-2.3	4.5	-2.8	8.9	-1.7	-1.4	-1.1	-1.3	-15.2	0.8	-16.7	-0.5	-5.1	-12.6	-0.5	-0.4
319	-4.2	-7	4.2	7.3	0.8	1.4	-3.9	10	1	0	-0.7	-1.5	-9.6	1	-7.1	-0.8	-6.5	-13.2	-1.9	-1.5
320	-5.8	-7	2.8	1.7	2	0.8	-8.5	3.4	-0.5	0.6	-6.4	-3.4	-11	-8	-10.7	-5.7	-5.4	-4.1	1.5	3.2
321	-4.2	-12	-3.3	-2.8	6.1	-5.6	-16.7	3.2	2.9	-0.1	-3.6	-3	-10.4	-18.7	-17.3	-6	-8.6	-1.3	-0.9	3.2
322	-6.7	-19.2	-4.2	-4.5	2	-11.4	-19.4	0.5	3.2	-1.3	-11.2	-1.5	-11.7	-17.1	-18.9	-0.8	-6.4	5.2	-1.2	-2.4
323	-7.8	-16.1	-5.3	-6.4	0.9	-16.6	-17.7	-1.9	1.5	-2.4	-17	-1	-7.7	-18.5	-17.9	-1.9	-4.5	3.3	-1.1	-2
324	-7.2	-10.8	-7.5	-5.6	-2.8	-18.9	-16.4	1.3	1	0.8	-19.9	-1.7	-4.7	-21	-13.8	4.1	-4.5	-1.9	-7.5	-2.8
325	-4.4	-14.8	-6.4	-9.8	-6.4	-18.5	-12.7	1.2	1.2	-0.8	-19.5	-4.1	-5.5	-21.7	-9.2	2.6	-4	-3.5	-14.4	-2.3
326	-1.1	-15	-7.8	-11.7	-3.1	-20.7	-11.1	3.1	-1.8	0.5	-13.8	-7.6	-2.4	-25	-12.4	-2	-2.5	-8.7	-15.4	-6.1
327	2.2	-17	-5.3	-13.9	2.5	-21.3	-3.3	-0.8	-5	-4.5	-11.6	-6.2	4.9	-18	-2.2	-1.1	-1.5	-9.3	-17.3	-9.5
328	0.6	-11.7	-2	-7.2	-0.6	-18.9	-1.3	0.2	-0.9	-5.8	-13	-9.2	-2.1	-24.3	2.3	-1.9	-3	-2.8	-22.3	-4.1
329	0.6	-10.3	-1.7	-3.6	-8.9	-11.9	0.6	-0.2	0.2	-3.8	-18.8	-11.4	-8.1	-28.3	-2.6	-0.4	-10.6	-8.9	-20.5	-0.7
330	0.9	-10.8	-1.4	-9.2	-12.5	-5.6	-4.6	-8.3	1.7	-3.1	-14.5	-10.1	-8.1	-31	2.6	-0.8	-16.4	-8.5	-15.9	-5.6
331	-6.4	-15.3	-2.5	-8.7	-9.5	-4.1	-2.5	-11.3	2.9	-3.9	-6.8	-5.2	-7.6	-23.2	-4.3	1.2	-12.5	-5.9	-8.2	-6.9
332	-7.3	-12.2	-3.6	-14.2	-3.7	-4.2	-4.4	-11.4	1.8	-1.7	-5.1	-6.9	-8.6	-17.7	-6.5	-0.8	-3.2	1.2	-5.4	-4.6
333	0.6	-14.8	-3.3	-18.4	-0.6	1.8	-13	-12.1	-6.2	2.8	-8.2	-11.3	-9.7	-19.2	-7.6	0.6	0.2	0.5	-0.2	-14.1
334	-7.2	-14.5	-5.9	-18.9	1.1	0	-16.8	-6.5	-17.2	-0.4	-11.5	-14	-9.4	-20.1	-4.9	-2.1	5.5	0	-13.9	-11.6
335	-17.5	-13.4	-2.3	-19.2	4.5	-3.8	-20.7	-2.9	-22	1.2	-7.2	-13.7	-11.1	-22.3	-4.7	-2.9	1.8	-0.6	-21.9	-14.2
336	-19.8	-13.4	-2.3	-15.3	2.8	-8.9	-13.3	-6.5	-20.8	0.4	-5.2	-12.3	-15.8	-18.8	-8.3	-1.5	-1.1	-2	-21.1	-19.7

Day	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
337	-20.9	-14.2	-5.9	-13.9	-2.8	-16.8	-2.3	-6	-20.2	-3.1	-5.7	-7.5	-12.1	-16.3	-12.1	-2.7	-3.8	2.2	-12.5	-18.5
338	-17.3	-13.9	-4.2	-20.9	-9.7	-25.4	-4.8	-1	-20.5	-3.2	-2.6	-9.8	-8	-6.3	-11.7	-0.5	3.7	2.7	0.9	-16.6
339	-20	-10.3	-0.3	-19.5	-17.3	-28.2	-13	2.4	-25.1	-2.4	-4.8	-6	-9.6	-0.1	-7.9	-1.2	1.4	-2.9	-1.8	-15.4
340	-23.6	-5.3	-3.4	-8.6	-16.4	-28.1	-13.1	-0.2	-26.1	-3.1	-11.8	-6.8	0.4	-2.8	-8.5	1.3	-5.8	-8.5	3.8	-12.3
341	-25	-4.8	-5	-5	-16.7	-29	-10.5	-6	-19.3	-3.9	-19.2	-16.9	3	-8.1	0.2	0.6	-12.7	-5.3	4	-13.3
342	-20.9	-5.6	2.3	0.6	-18.9	-31.3	-8.9	-1.2	-15.5	-6.2	-11.2	-24.5	-0.3	-8.7	-9.2	-1.8	-12.1	-5.2	5.1	-9.1
343	-13.1	-4.2	2.5	-1.1	-20.6	-33.1	0.5	-3.8	-22.5	-5.4	-6.6	-19.9	-2.7	-10.1	-8.4	-3.1	-7.1	-13.4	-1.8	-1.8
344	-10	-2.2	-2.2	-15.9	-4.5	-27.1	-3.8	-13.9	-20	-8.9	-12.1	-18.9	-11.3	-8.9	1.2	-0.8	-2.5	-20.2	-4.4	-0.6
345	-10.3	-6.7	-5.8	-23.7	-17.5	-20.1	-4.9	-12.6	-5.8	-9.1	-9.6	-16.3	-18.8	-10	-0.6	-1.3	0	-9.2	-5	-4.1
346	-18.7	-16.4	-3.9	-20.3	-10.3	-11.6	-5.8	-14.2	-6.1	-10.2	-7.4	-14.7	-14.2	-19.4	-4.5	-1.9	1.3	-1.9	-9.6	-8.4
347	-17.8	-20.8	-8.1	-24.2	0.9	-7.8	-3.6	-22.9	-6.7	-13	-8.1	-14.2	-9.5	-7.7	-2.7	-5.9	-2.7	-2.3	-10.2	-10.4
348	-14.8	-21.7	-6.4	-14.8	-0.6	-8.5	0.3	-25.1	0.2	-16.7	-7.1	-21.8	-10.5	-2.9	-7.1	-5.3	-6.3	-2.1	-4.2	-6.1
349	-11.4	-16.4	-3.1	-14.8	0	-8.5	-3.5	-28.1	7	-10.4	-3.6	-22	-22.8	-5.6	-4.5	-6.2	-2.1	-3.4	-9.5	2
350	-11.1	-10.6	-1.1	-23.6	2.5	-7.2	-6.8	-20.6	3	-8.6	-3.6	-24.2	-25.6	-3.6	-1.3	-9.7	-0.6	-9.3	-15	-1.2
351	-15	-5.6	-0.6	-11.1	-3.1	-8.2	-13.6	-13	-9.7	-8.6	-5.5	-23.3	-25.1	-1.5	-4	-11.5	0.9	-18.5	-12	-6.7
352	-9.2	-8.1	-6.4	0.9	-6.2	-11.9	-15.4	-2.8	-20.5	-5.2	-6.3	-24.4	-11.7	2	-3	-4.4	0.4	-22.5	-23.7	-9.4
353	-6.4	-8.1	-1.7	1.4	-11.1	-15.4	-11.6	3.1	-22.6	-6.2	-10.8	-29.5	-3.5	0.3	-6.6	-2.6	-3	-25.4	-28.8	-5.7
354	-6.1	-3.4	-3.4	-2	-5.6	-12.2	-3	0.7	-21	1.4	-9.4	-25.6	-10.3	4.4	-5.9	-3.4	-7.9	-2.5	-29.7	-2.8
355	-8.1	-1.2	-3.3	-6.2	-3.1	-7.7	-4.5	-4.8	-20.1	-1.9	-10.4	-22.1	-23.2	5.7	-1.6	-3	-11.3	-27.8	-26.5	2.7
356	-18.9	-4.5	-9.5	-7.8	-6.7	-9.9	-13.4	-5.1	-19.7	-5.8	-11.1	-24.6	-21.8	6.3	-4.2	-3.5	-9.1	-10.6	-16.4	-1.3
357	-23.6	-9.2	-13.1	-3.1	-1.1	-13.3	-14.7	-8.6	-23.6	-6.6	-13.8	-29.5	-25.4	2.5	-0.6	-5.2	-7.8	4.3	-8.1	-2.4
358	-13.3	-7.8	-3.1	-1.7	-2.8	-15.7	-4.8	-5.5	-21.1	-8.2	-9.9	-25.4	-21.1	2.1	-3.3	-3.9	-12.9	5.1	-14.2	-2.3
359	-7	-4.7	2.5	-0.6	-4.8	-11.3	-6	-7.3	-18.1	-8.7	-6.1	-13	-22.3	4.5	-4.1	3.1	-15.6	5	-22	-2.7
360	0.3	-6.9	-3.9	-3.1	-6.4	-9.9	-10.8	-3.2	-11.3	-11.5	-8.9	-12.3	-26.5	-1.2	-1.4	-0.3	-16.6	4.6	-7.9	-1.9
361	-3.4	-9.8	-7.5	1.4	-8.6	-5.7	-18.1	-1.2	-11.1	-20.2	-14	-14.4	-28.2	-6.8	-0.6	-1.1	-15.1	1.9	-14.1	-2.5
362	-9.2	-15.3	-7.8	-3.3	-10.3	-3.6	-23	-4.6	-11.3	-23.6	-5.4	-16.6	-28.4	-8.8	-2.5	-7.5	-11.4	-0.5	-31.1	-8.3
363	-11.1	-21.7	-2.5	0	-14.5	-9.6	-25.3	-2.4	-2.5	-23.2	-3.6	-18.2	-30.6	-2.8	-0.7	-9.6	-6.5	0.5	-27.3	-10
364	-15	-23.4	-2.8	-5	-13.9	-12.3	-28.6	-5.4	0.2	-24.9	0.8	-13.8	-27.4	-2.3	-0.7	-15.4	-15.4	-1	-18.7	-8.1
365	-8.4	-18.6	-4.2	-12.8	-12.3	-16	-22.2	-8.1	-5.1	-25.7	0.4	-2.7	-20.7	-2.8	-6	-14.3	-21.5	-2	-21.7	-6.4

APPENDIX D: NEURAL NETWORK DATA

The data used in Chapter 4 to train the neural network for earthwork productivity is presented in Table D-1. The numbers used are representative of actual productivity values that would be observed in practice. They represent the type of "fuzzy" data that is obtained from actual situations.

TABLE D-1 EARTHWORK PRODUCTIVITY DATA

Average Daily Temperature	Precipitation (mm)	Precipitation Sum 7 Days Previous (mm)	Productivity Factor
8.93	0.00	0.20	1.29
14.75	0.00	0.20	1.44
16.36	0.00	0.20	1.39
14.20	0.00	0.20	1.38
11.64	0.00	0.20	1.30
13.13	2.77	2.77	1.28
12.41	3.07	5.84	1.08
8.78	0.00	5.84	1.27
11.88	2.72	8.57	1.08
16.94	0.49	9.05	1.11
16.92	0.00	9.05	1.29
12.79	0.00	9.05	1.17
16.45	0.00	6.28	1.16
14.53	0.00	3.21	1.23
16.66	0.00	3.21	1.20
16.35	0.00	0.49	1.37
21.57	0.00	0.00	1.33
23.05	0.00	0.00	1.30
21.06	0.00	0.00	1.27
18.68	0.00	0.00	1.38
15.17	13.94	13.94	0.00
11.54	0.00	13.94	1.11
11.71	0.00	13.94	1.15
16.08	9.86	23.80	0.78
15.69	0.56	24.36	1.12
14.46	0.63	24.99	1.09
12.94	2.70	27.70	0.90
14.66	0.00	13.76	1.30
16.49	0.86	14.62	1.06
16.43	0.00	14.62	1.06
12.15	0.25	5.01	1.22
13.92	12.03	16.48	0.00
13.01	12.13	27.98	0.00
12.26	0.73	26.00	0.96
8.44	1.27	27.27	0.88
8.97	10.26	36.66	0.61
11.23	0.00	36.66	0.85
13.98	0.00	36.42	0.97
14.07	2.62	27.01	0.97
12.72	1.12	16.00	1.20
12.86	9.81	25.08	0.77
17.98	0.00	23.81	1.09
15.13	0.32	13.87	1.11
19.84	0.00	13.87	1.20
19.30	1.59	15.46	1.17
18.14	0.00	12.85	1.20

Average Daily Temperature	Precipitation (mm)	Precipitation Sum 7 Days Previous (mm)	Productivity Factor
16.70	9.12	20.84	0.79
20.68	0.00	11.04	1.21
18.15	0.00	11.04	1.27
19.78	0.00	10.71	1.20
19.57	0.00	10.71	1.14
16.55	2.56	11.68	1.08
14.56	10.55	22.24	0.76
22.09	0.00	13.12	1.25
25.26	3.51	16.63	0.94
20.71	10.46	27.08	0.63
25.68	15.76	42.84	0.00
23.25	0.15	42.99	0.97
17.46	13.95	54.37	0.00
19.67	10.00	53.82	0.00
13.24	0.89	54.71	0.00
17.70	5.24	56.44	0.00
21.74	3.08	49.07	0.00
23.50	0.00	33.31	1.04
24.27	0.00	33.17	0.97
22.10	0.00	19.22	1.19
23.42	0.00	9.22	1.21
20.57	10.98	19.30	0.63
27.10	0.00	14.06	1.16
26.37	0.00	10.98	1.17
19.57	13.21	24.19	0.00
18.35	0.21	24.40	1.07
14.76	2.01	26.41	1.09
19.70	21.64	48.05	0.00
23.87	0.00	37.07	0.88
21.74	0.22	37.30	0.90
20.50	16.22	53.52	0.00
22.50	0.00	40.31	0.81
16.59	1.40	41.50	0.87
17.35	1.05	40.54	0.91
16.14	0.11	19.01	1.07
17.43	5.27	24.28	0.91
16.41	0.47	24.54	1.10
13.98	2.67	10.98	1.22
20.24	3.90	14.88	0.98
20.03	1.14	14.62	1.19
18.54	0.47	14.04	1.24
19.84	0.00	13.92	1.18
19.38	0.00	8.65	1.30
20.32	0.00	8.18	1.13
22.90	0.00	5.51	1.25
21.47	0.68	2.29	1.31

Average Daily Temperature	Precipitation (mm)	Precipitation Sum 7 Days Previous (mm)	Productivity Factor
22.05	0.94	2.09	1.25
19.45	4.54	6.16	1.12
15.62	12.28	18.44	0.00
24.44	0.00	18.44	1.02
25.28	0.00	18.44	1.06
26.17	0.00	18.44	1.22
19.46	1.77	19.53	0.99
25.77	0.00	18.59	1.05
21.90	0.00	14.05	1.17
20.42	0.00	1.77	1.33
26.87	0.00	1.77	1.22
23.79	0.14	1.91	1.21
20.94	12.84	14.75	0.00
19.62	0.00	12.98	1.27
15.48	0.32	13.30	1.19
19.48	0.00	13.30	1.12
15.88	0.00	13.30	1.15
18.87	0.00	13.30	1.22
14.78	2.06	15.22	1.15
12.43	2.16	4.54	1.28
15.83	0.00	4.54	1.30
17.49	0.00	4.22	1.24
15.79	0.00	4.22	1.17
14.82	0.00	4.22	1.38
12.25	10.88	15.10	0.73
10.64	0.00	13.04	1.14
16.63	0.00	10.88	1.22
23.41	0.00	10.88	1.23
14.99	2.90	13.78	1.20
18.02	1.51	15.29	1.08
12.24	7.32	22.61	0.84
11.56	0.02	11.75	1.17
11.18	5.13	16.88	1.00
10.95	2.83	19.70	1.03
14.99	0.00	19.70	1.24
16.22	0.00	16.80	1.09
14.56	0.00	15.30	1.15
12.27	0.00	7.98	1.32
8.89	20.28	28.23	0.00
9.86	8.89	31.99	0.67
17.18	0.00	29.17	1.05
14.48	6.56	35.73	0.82
17.05	1.08	36.81	0.89
12.68	3.68	40.49	0.86
14.11	4.18	44.67	0.68
13.15	0.00	24.40	1.02

Average Daily Temperature	Precipitation (mm)	Precipitation Sum 7 Days Previous (mm)	Productivity Factor
14.80	0.00	15.50	1.17
13.99	0.00	15.50	1.17
11.95	0.00	8.94	1.30
9.27	0.00	7.86	1.18
9.41	0.00	4.18	1.32
16.03	0.00	0.00	1.27
15.88	0.00	0.00	1.23
13.21	0.00	0.00	1.34
13.89	0.00	0.00	1.31
14.97	0.00	0.00	1.29
16.19	0.00	0.00	1.22
7.12	0.00	0.00	1.29
3.38	0.00	0.00	1.24
4.22	1.05	1.05	1.25
8.00	0.00	1.05	1.22
9.09	0.00	1.05	1.34
8.98	0.00	1.05	1.19
11.17	0.00	1.05	1.33
8.56	3.74	4.79	1.12
13.94	0.00	4.79	1.38
16.21	0.00	3.74	1.36
17.27	0.00	3.74	1.26
11.74	0.00	3.74	1.20
15.04	0.00	3.74	1.33
22.15	0.00	3.74	1.32
16.38	0.00	0.00	1.25
13.91	0.00	0.00	1.42
9.83	0.00	0.00	1.33
2.65	0.00	0.00	1.21
6.82	0.00	0.00	1.18
6.79	0.00	0.00	1.25
2.35	0.00	0.00	1.12
2.67	0.00	0.00	1.21
4.46	0.00	0.00	1.29
-2.65	0.33	0.33	1.18
3.76	0.00	0.33	1.27
0.41	0.74	1.07	1.12
2.88	0.00	1.07	1.19
-4.26	0.00	1.07	1.09
-2.21	0.25	1.32	1.20
-1.01	7.94	9.26	0.70
0.00	0.00	8.93	1.08
7.78	0.00	8.93	1.24
6.03	0.00	8.19	1.21
2.25	0.00	8.19	1.17
-6.53	0.77	8.96	0.90

Average Daily Temperature	Precipitation (mm)	Precipitation Sum 7 Days Previous (mm)	Productivity Factor
0.76	0.00	8.71	1.18
1.85	0.00	0.77	1.19
1.52	0.00	0.77	1.25
-3.01	0.00	0.77	1.21
-4.32	0.00	0.77	1.11
-12.76	4.25	5.02	0.78
-3.42	0.00	4.25	1.05
-3.57	0.00	4.25	1.06
-1.31	0.00	4.25	1.12
-10.27	2.08	6.33	0.81
-8.18	0.00	6.33	0.95
1.66	0.00	6.33	1.17
2.19	0.43	2.51	1.06
4.69	1.00	3.50	1.06
8.45	0.00	3.50	1.21
8.38	0.00	3.50	1.21
0.43	0.18	1.61	1.12
-6.28	0.00	1.61	1.14
-4.64	0.00	1.61	1.18
-7.01	0.00	1.18	0.98
-11.20	1.50	1.67	0.91
-13.78	10.47	12.14	0.51
-11.07	0.00	12.14	0.87
-10.91	0.00	11.96	0.97
-2.79	0.00	11.96	1.07
-6.85	0.00	11.96	0.87
-9.98	0.00	11.96	0.92
-9.75	0.00	10.47	1.00
-3.85	0.00	0.00	1.16
4.76	0.00	0.00	1.12